More on … *The Event-Related Potential* (*aka* the ERP)

International Trans Day of Visibility,
International Trans Day of Visibility,

Announcements 4/21/25

- Paper/Proposal Guidelines available
  - On course webpage
  - Link in D2L
- Paper/Proposal two paragraph prospectus due via D2L no later than *TODAY* (OK, tonight…)
- Student Course Surveys – complete by last day of class (May 5)
- Attendance/Comments – remember and check!
- 501B Lab Section
  - Complete DFA data processing by last night, report due Friday. (Guideline for report ready this evening)
  - ERP analysis: We will meet on Wednesday 3 pm in room 323

Feedback and Questions

From your experience, how standardized can preprocessing really be? If different groups, individuals, or devices follow the same pipeline, are the results generally robust and comparable most of the time?

frontiers in Neuroscience

METHODS
published: 07 June 2021
doi: 10.3389/fnins.2021.660449

Check for updates

EPOS: EEG Processing Open-Source Scripts

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Background: Since the replication crisis, standardization has become even more important in psychological science and neuroscience. As a result, many methods are being reconsidered, and researchers' degrees of freedom in these methods are being discussed as a potential source of inconsistencies across studies.

New Method: With the aim of addressing these subjectivity issues, we have been working on a tutorial-like EEG (pre-)processing pipeline to achieve an automated method based on the semi-automated analysis proposed by Delorme and Makeig.

Feedback and Questions

On the slide discussing lateralized task effects, it was noted that the participants were right-handed. Has there been a study that involved left-handed participants? Do you think we would see anything unusual in those who are left-handed but were forced to write with their right hand?

Feedback and Questions

I know we're just going through the basics of these methodologies, but I was wondering if you've heard much about Markov modeling. I've been working with a postdoc in the NET Lab, Yuhua Yu, and she uses it for analyzing EEG and fMRI data, I'm guessing mainly because she's interested in spontaneous thought, and I find it really fascinating, but it also seems like magic to me!

Core Concepts of Markov Models

1.States: Discrete conditions or *configurations* that the system can be in.

2.Transition Probabilities: The probabilities of moving from one state to another.

3.Initial State Distribution: Probability of starting in each possible state.

Sample use cases

Sleep Staging:

•States = sleep stages (Wake, N1, N2, N3, REM)

•EEG features = power in delta, theta, alpha bands

•Transitions = probabilities of moving between stages over time

Seizure Detection:

•States = interictal, preictal, ictal

•Emissions = raw EEG or engineered features

•Model can learn typical seizure onset dynamics

Feedback and Questions

How do you conceptualize the difference and the integration between foreground (a specific cognitive task) and background (i.e., depressed mood) processing using an EEG/ERP lens? I.e., are there specific global-to-local dynamics, nested frequency distributions, or scale-free activity dynamics (i.e., power law distributions) that lead to a mutually dependent reciprocal influence between foreground and background processing?

Feedback and Questions

It seems like the ERP can be used to measure emotional reactions based on the dimensional perspective through showing participants emotion-arousing pictures.

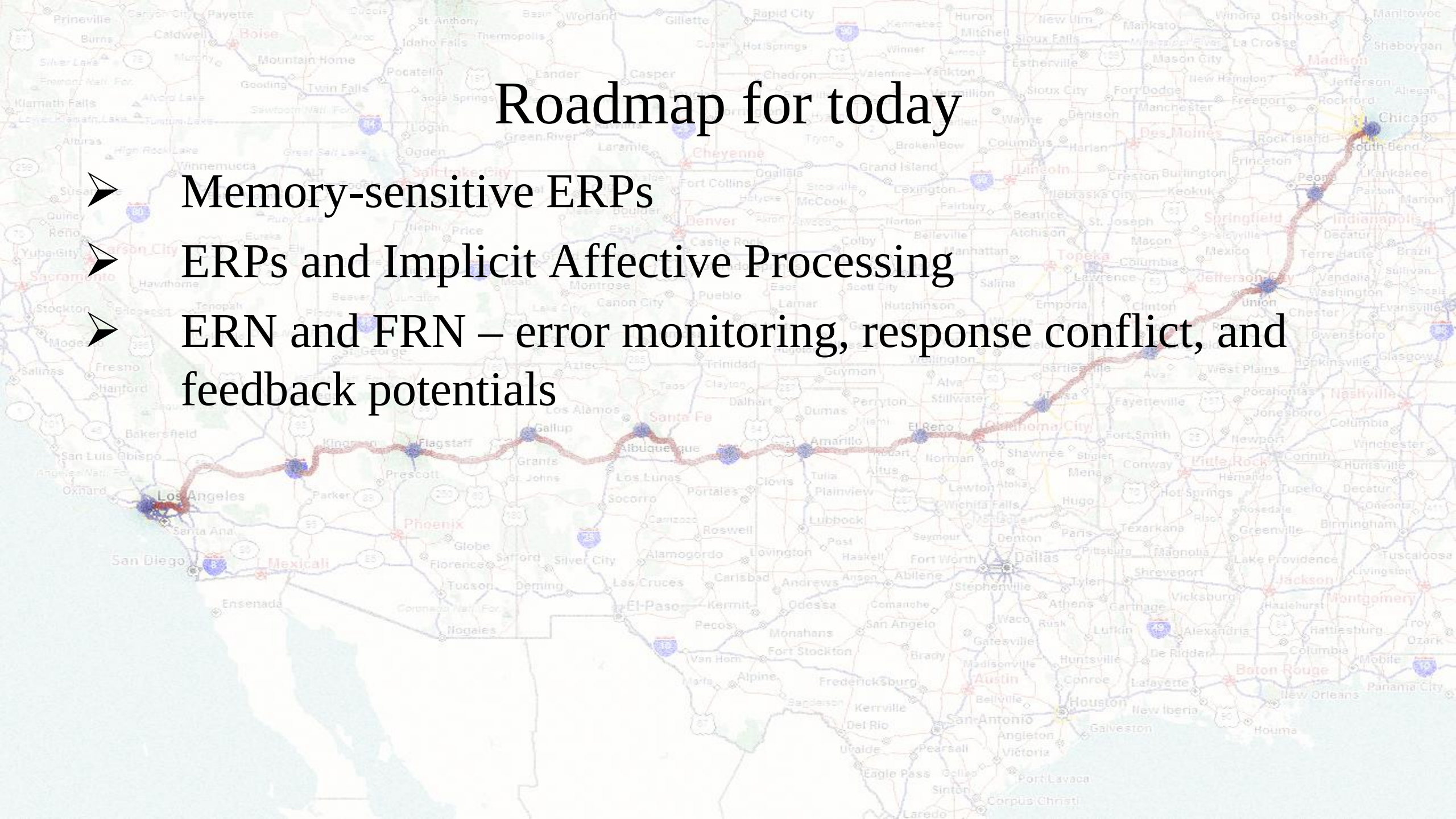
Feedback and Questions

[We discussed how P300 can have an increased amplitude relative to the probability of occurrence. In a card gambling context where there are (general) probabilities of certain cards to be turned over that may be] understood better by professionals than the general public, and the fact that select cards flipped over would have different valences relative to a current hand held, would we expect differential amplitudes in the P300 relative to a general probability of a flipped card and its valence in both a general individual and in a poker professional (and compare the two)?.

Feedback and Questions

Roadmap for today

- Memory-sensitive ERPs
- ERPs and Implicit Affective Processing
- ERN and FRN – error monitoring, response conflict, and feedback potentials



ERPs and Memory

- Several components may be sensitive to recognition
  - Likely episodic recollection
- Sensitive to Encoding

Repetition Priming Effects

- Robust effect that repeated items produce an enhanced late positivity across a broad latency range
- Magnitude of effect related to strength of memory trace

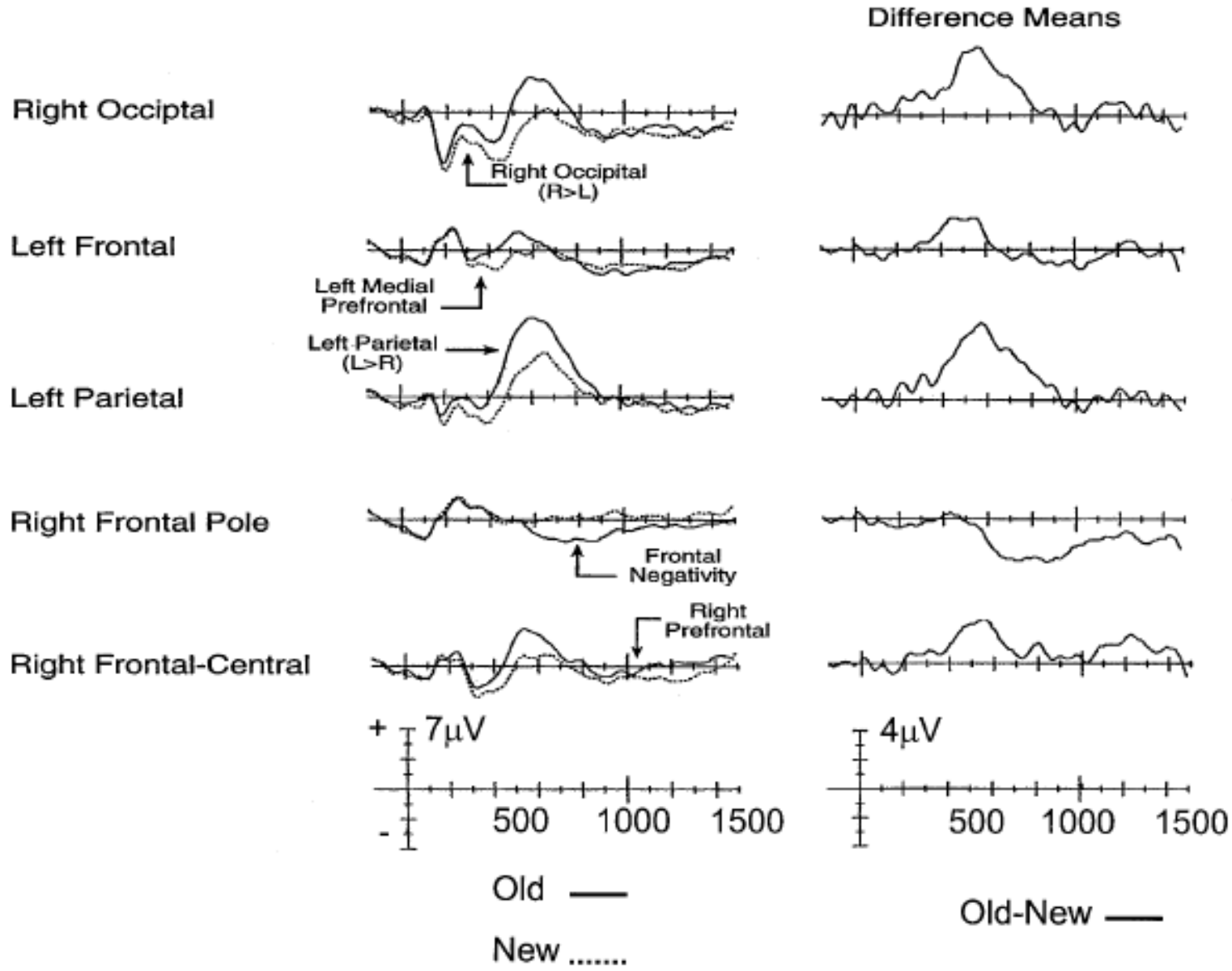
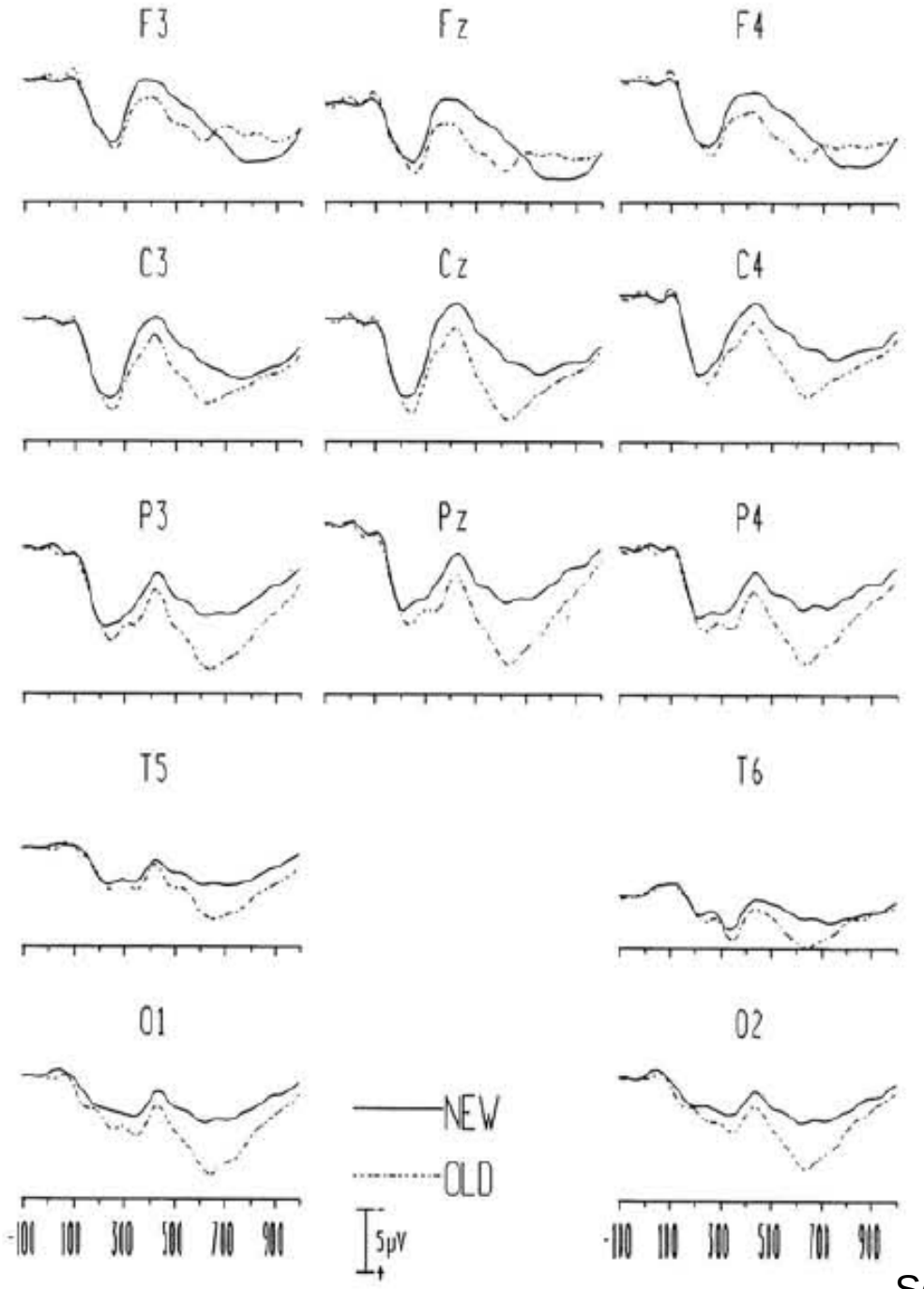


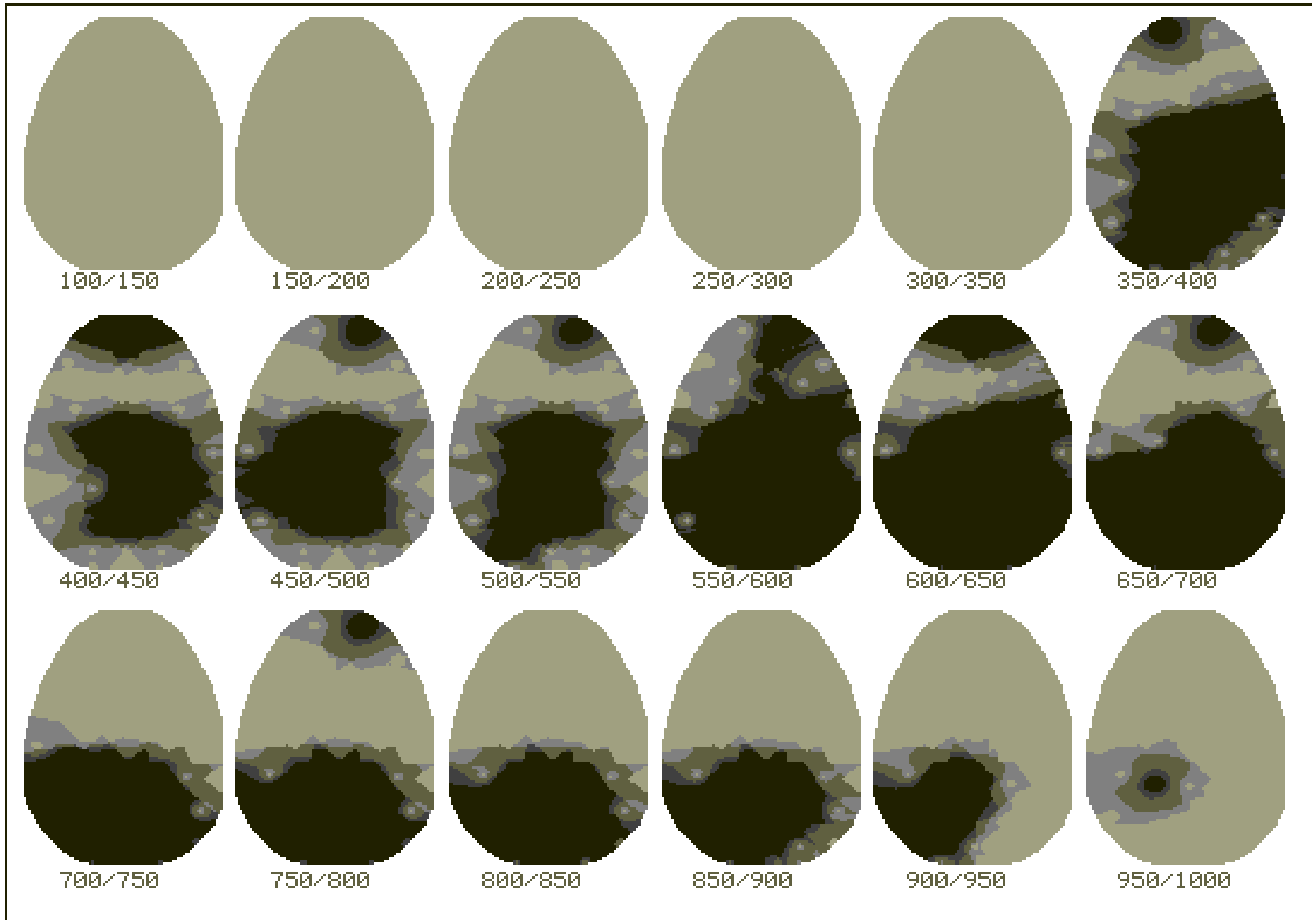
Fig. 4. Grand mean ERP waveforms elicited by correctly recognized old and correctly rejected new items from Johnson et al. (1998a). The left column depicts the old and new waveforms at the electrode site and hemiscalp where that subcomponent was largest. Repoduced from Johnson et al. (1998a) with permission of the publisher.

Repetition Priming

- Are there repetition effects that do not depend on the subjective awareness of the subject?
  - Can use Masked Priming to examine (Schnyer, Allen, Forster, 1997)

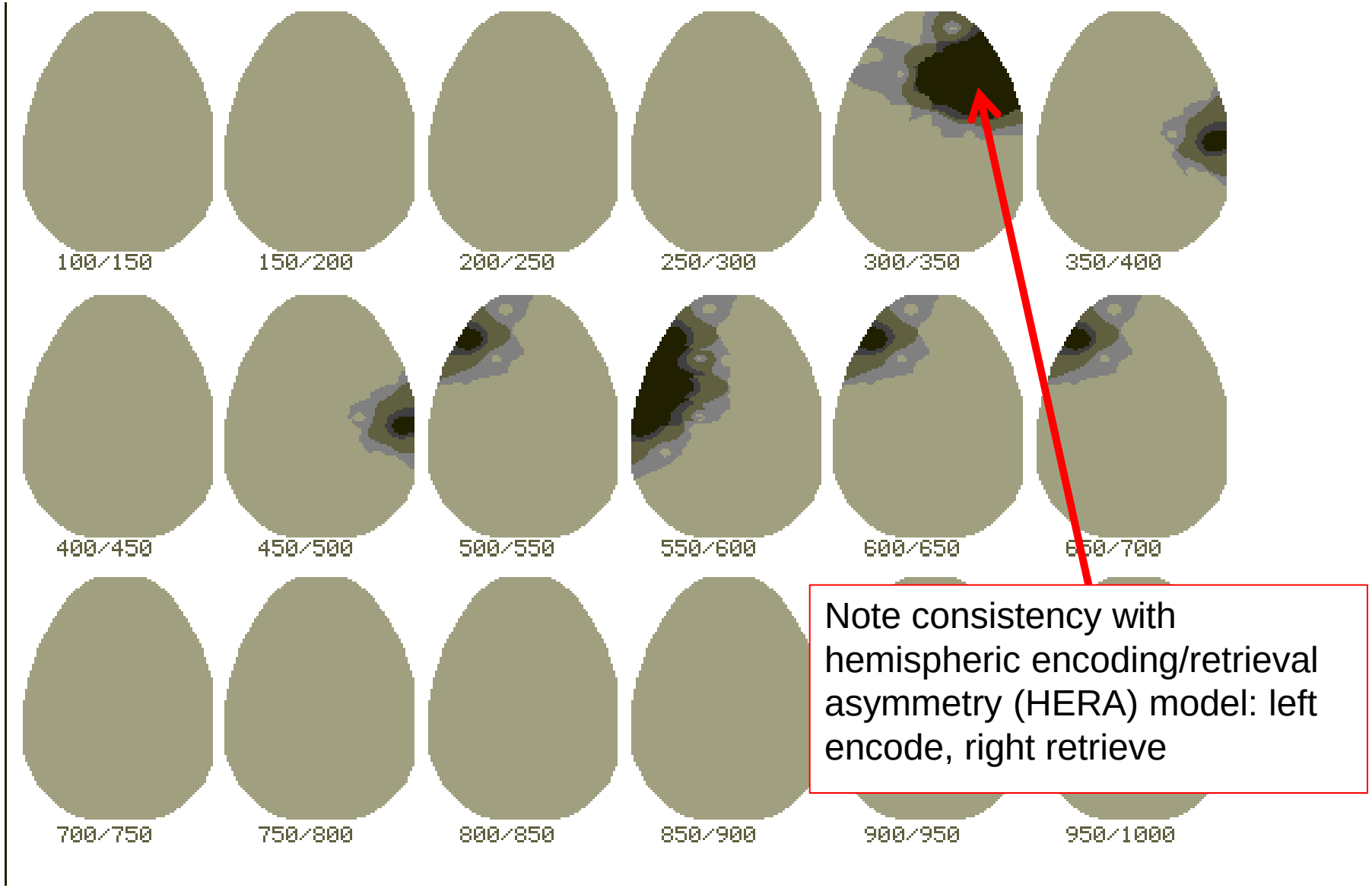


Schnyer, Allen, Forster, 1997



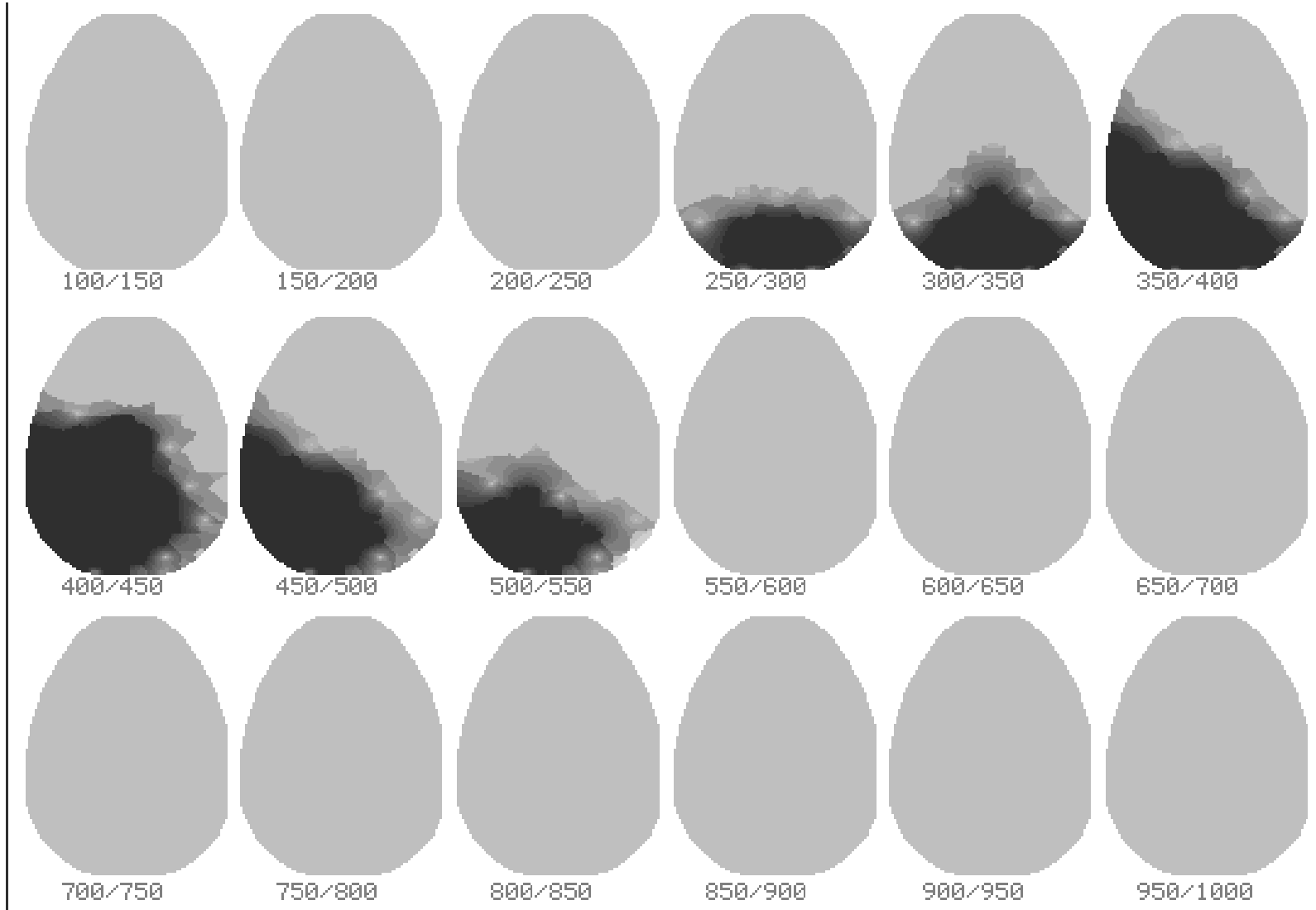
Standard Repetition Effect for Words Seen Unmasked in Previous Blocks
Task is to make OLD-NEW decision

Schnyer, Allen, Forster, 1997



Standard Repetition Effect for Words Seen Unmasked in Previous Blocks
But Task is to make WORD-NONWORD decision

Schnyer, Allen, Forster, 1997

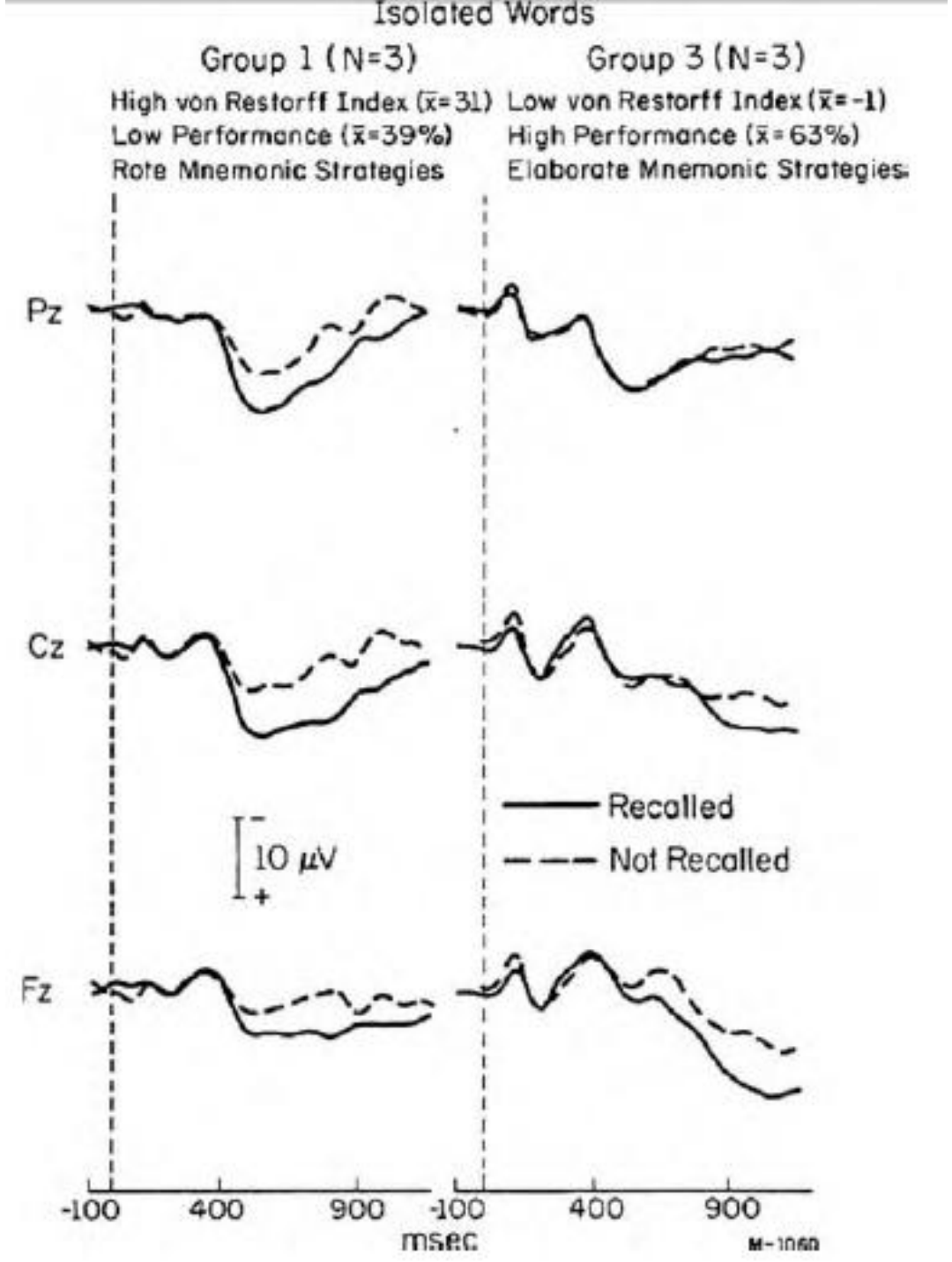


Masked Repetition Priming Effect for Words Presented only a Trial Previously

Schnyer, Allen, Forster, 1997

Memory Encoding

- Words subsequently remembered show enhanced positivity at encoding
- Strategy interacts, however



Von Restorff Index (AKA the isolation effect) refers to the phenomenon where an item that "stands out like a sore thumb" is more likely to be remembered than other items

Note prototypic DM effect on left, but not on right for those that used elaborative strategies. Note enhancement over frontal lead for these latter subjects.

Figure 4.12. ERPs elicited by "isolated" words that were later recalled (solid line) or not-recalled (dashed line). The left column shows ERPs for subjects who used rote mnemonic strategies; the right column shows ERPs for subjects who used elaborative strategies. Note that the amplitude of P300 is related to subsequent recall for the rote memorizers, but not for elaborators. (Copyright 1986, Elsevier Science Publishers. Reprinted with permission of the publisher from Fabiani, Karis, & Donchin, 1986b.)

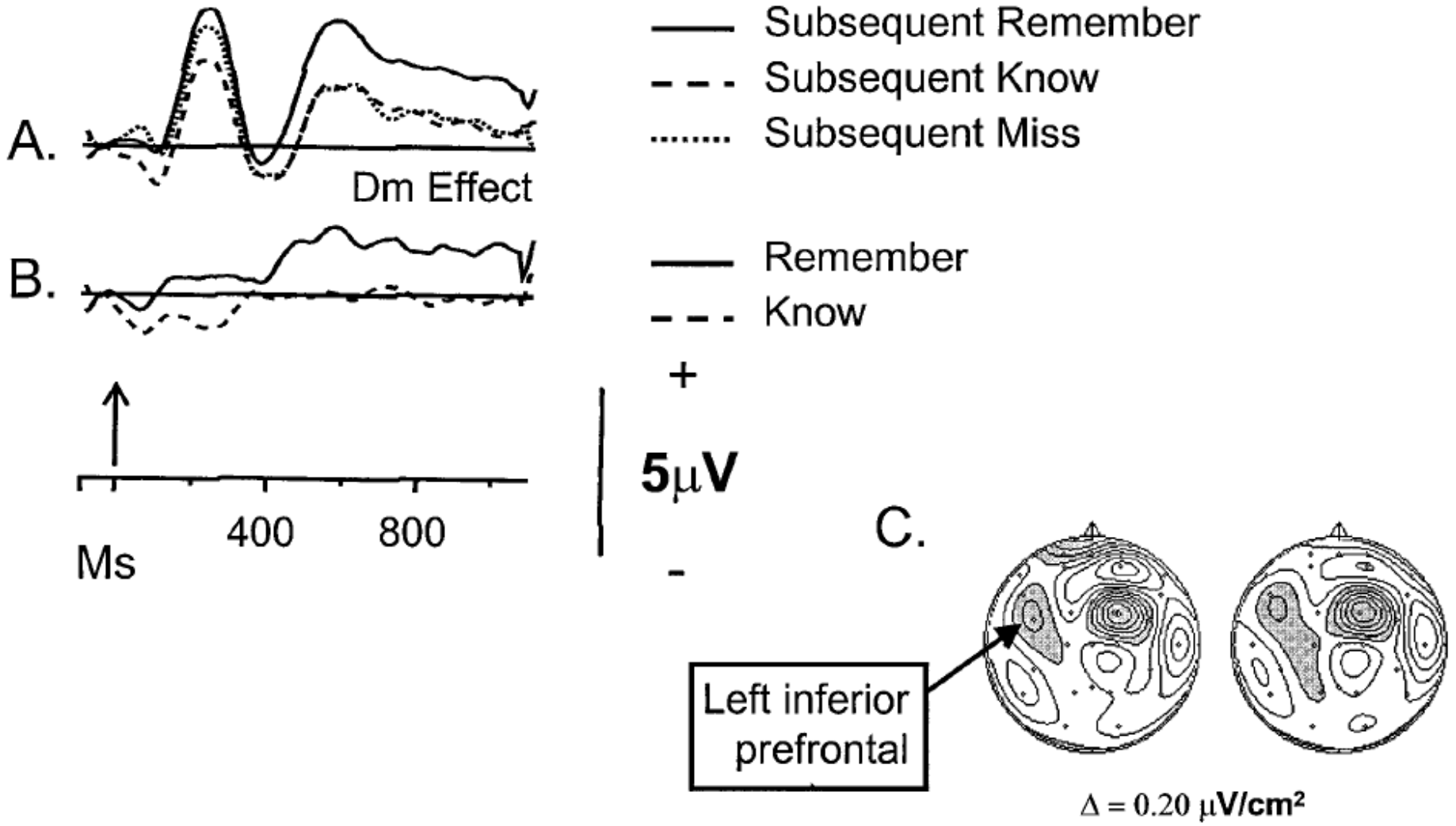


Fig. 3. **A:** Grand mean ERPs elicited by study items that were subsequently associated with remember or know judgments (hits) or were unrecognized (misses) during the subsequent recognition test. **B:** Grand mean difference waveforms computed by subtracting the ERPs to study items subsequently missed from those that were subsequently associated with either a remember or know judgment (Modified from Friedman and Trott, 2000). **C:** CSD maps for 2 intervals (500–800; 810–1,100 ms) measured in the Dm waveform associated with a subsequent Remember judgment. Data in A and B recorded at a left inferior prefrontal scalp site.

Indirect Assessments of Recognition

- Can the ERP detect recognition, independent of subjects' overt responses?
- Three applications
  - Clinical Malingering
  - Forensic Assessment
  - Clinical Disorder

Indirect Assessments of Recognition

- Can the ERP detect recognition, independent of subjects' overt responses?
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  - Clinical Malingering
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ERP Memory Assessment Procedures

- Learn a list of words
- Learn a second list of words
- Task: Concealed (1st list) and Nonconcealed (2nd list) words appear infrequently

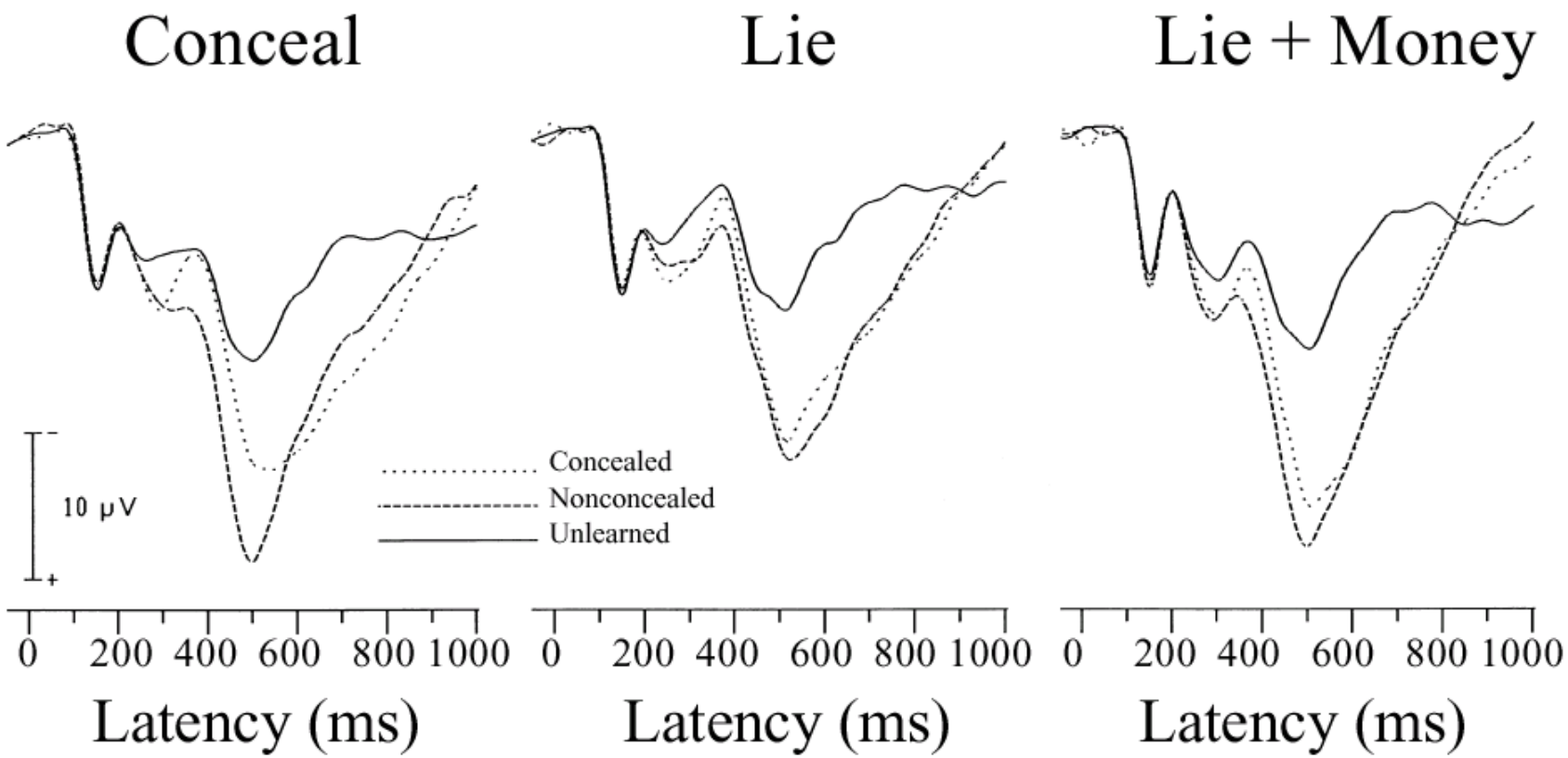
Item Type	Probability	Response	P3 Amplitude
Nonconcealed	1/7	"Yes"	Large
Concealed	1/7	"No"	Large if Recognized Small if not Recognized
Unlearned	5/7	"No"	Small

- Similar to procedures by Rosenfeld et al, Farwell & Donchin

The Classic Oddball Experiment

Motivational Variations

Conceal	Lie	Lie + $$
➢"YES" for words *JUST* learned, "NO" for all others	➢"YES" for words learned	➢"YES" for words learned
➢*Try to hide the fact that you learned the first list of words I taught you*	➢*Lie about words from the first list I taught you*	➢*Lie about words from the first list I taught you*
		➢*$5.00 incentive*



After Allen & Iacono, 1997

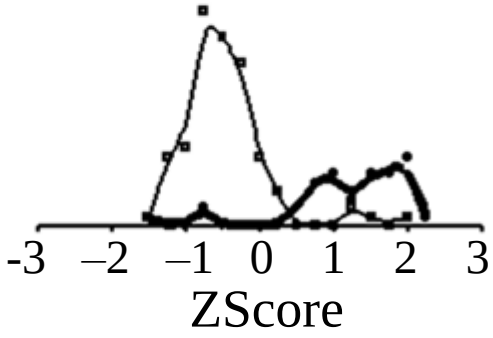
The Challenge

To provide statistically supported decisions for each and every subject, despite considerable individual variability in ERP morphology

P3 Amplitude

Sensitivity = .925

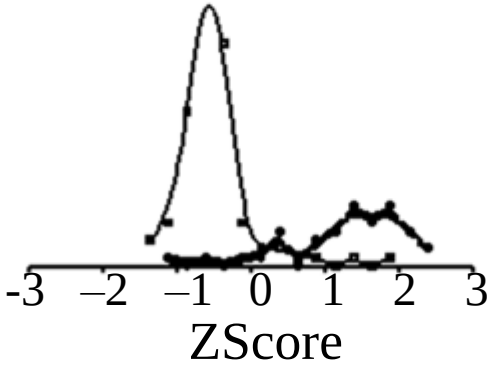
Specificity = .920



Raw ERP H^2

Sensitivity = .950

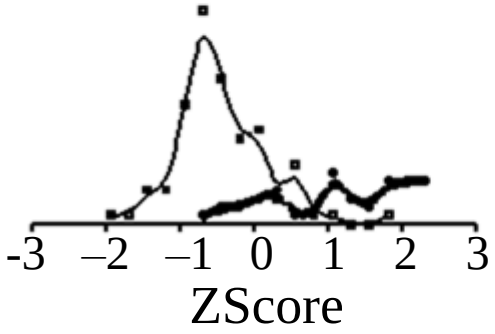
Specificity = .920



1st Derivative H^2

Sensitivity = .875

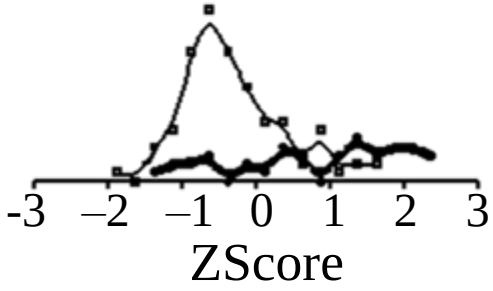
Specificity = .810



2nd Derivative H^2

Sensitivity = .750

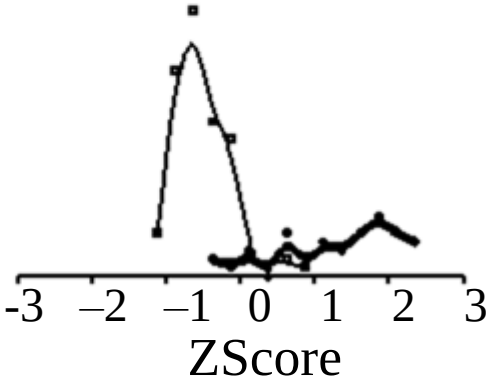
Specificity = .740



Deviation H^2

Sensitivity = .925

Specificity = .920



Bayesian Combination of ERP Indicators: Probability that an ERP was elicited by Learned Items

	List						
	Learned		Unlearned				
Subject	NonConceal	Conceal	U1	U2	U3	U4	U5
#01	1.0	0.999	0.000	0.000	0.000	0.000	0.001
#02	1.0	1.0	0.000	0.000	0.000	0.000	0.000
#03	1.0	0.999	0.000	0.000	0.000	0.002	0.000
#04	1.0	1.0	0.000	0.001	0.002	0.000	0.000
#05	1.0	0.971	0.002	0.000	0.000	0.000	0.000
#06	1.0	0.999	0.000	0.000	0.000	0.000	0.000
#07	0.983	1.0	0.000	0.000	0.000	0.000	0.000
...							
#18	0.996	0.983	**0.874**	0.001	0.000	0.000	0.000
#19	**0.009**	**0.214**	**0.971**	0.000	0.002	0.189	**0.983**
#20	1.0	0.999	0.002	0.000	0.009	0.000	0.214

Note: Only trials in which subjects did not acknowledge concealed items included

Classification Accuracy based on ERPs

	Learned (true pos)	Unlearned (true neg)
Conceal	0.95	0.96
Lie	0.93	0.94
Lie + $$	0.95	0.98
Combined	0.94	0.96

Allen, Iacono, & Danielson, *Psychophysiology,* 1992

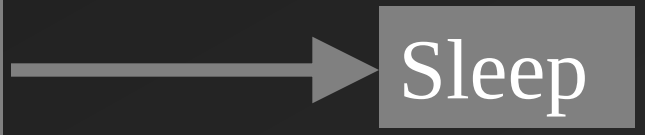
Extensions from Lab to Life…

- Two tests of the robustness of this procedure:
  - False recollections
  - Virtual Reality Mock Crime

A Laboratory Paradigm for False Recollections: DRM

- Subjects presented with 15 words highly associated with an omitted critical item

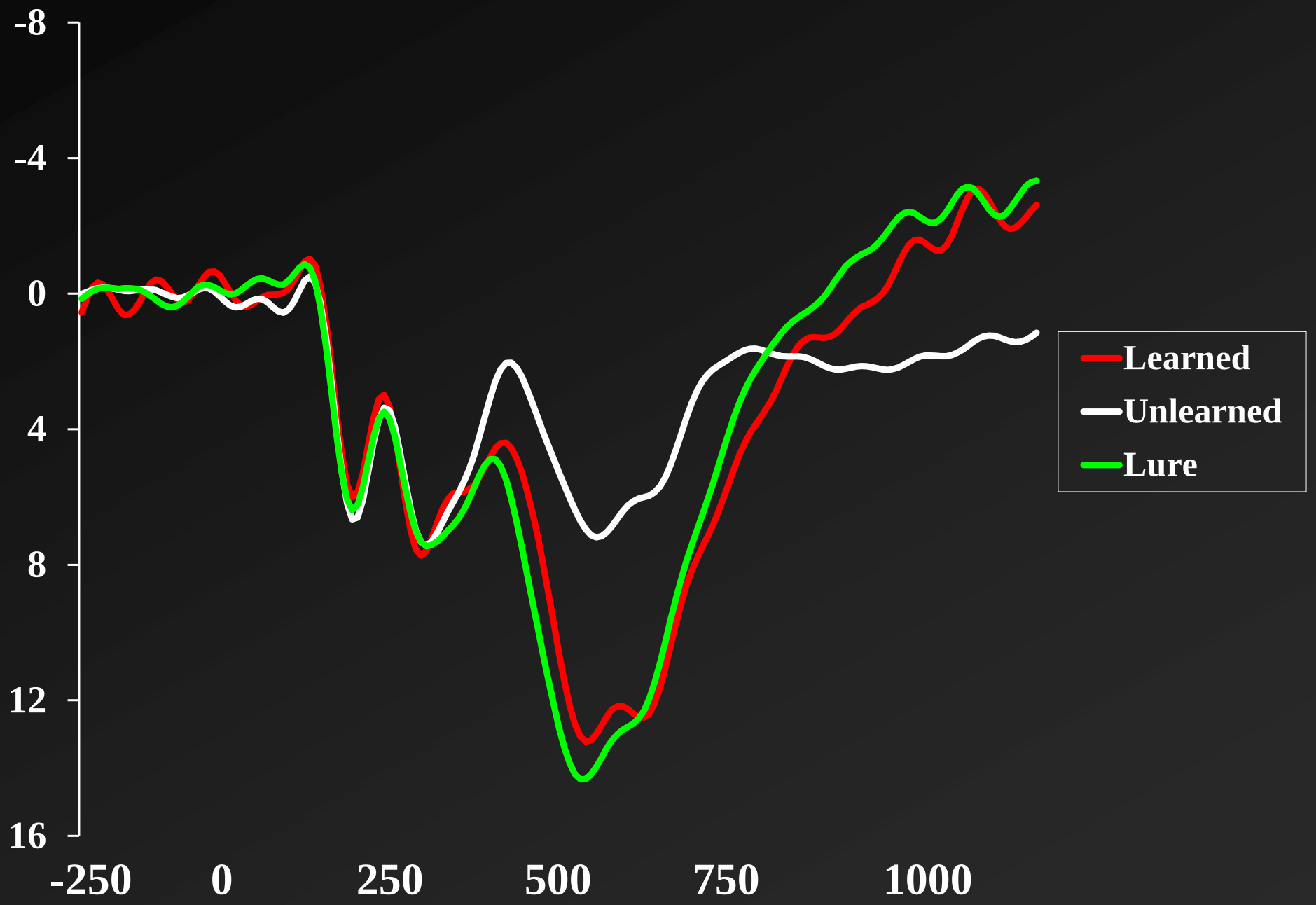
Bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy



Sleep

Reported Rates of Recogntion

Allen and Mertens (2008)



Allen and Mertens (2008)

The Box Score Blues

	Test Verdict
Ground Truth	Recognized
Actually Learned	56%
Critical Lure	72%
Unlearned	4%

- Highlights the need to have memorable items in the test
- Suggests limited utility in substantiating disputed memories; e.g., claims regarding recovered memories
- Still has low false positive rate when person denies knowledge

Virtual Reality Mock Crime

- Subjects received email detailing their “Mission”
- Sneak into graduate student office to break in to virtual apartment
- Apprehended and interrogated using ERP-based procedure
- Some subjects given details about utilizing countermeasures
- Innocent subjects tour the same virtual apartment, but with different objects and details.

SEALED ENVIRONMENTS

ARIZONA DAILY WILDCAT online

Let's smoke pot

Friday December 6, 2002 | wildcat.arizona.edu | online since 1994

UA News
Sports
·Basketball
·Football
Opinions
Features
GoWild
Police Beat
CatCalls
Comics
Crossword
Online Crossword
WildChat
Classifieds

THE WILDCAT
Write a letter to the Editor
Contact the *Daily Wildcat* staff
Search the *Wildcat* archives
Browse the *Wildcat* archives

Police Beat

By David Halperin
Arizona Daily Wildcat
Friday December 6, 2002

Suspicious e-mail sent

An employee reported that he received an e-mail Wednesday stating he is supposed to commit a crime today, reports stated.

At about 11:35 a.m., the employee told police he had received the suspicious e-mail while in his office at the Arizona Health Sciences Center, 1501 N. Campbell Ave.

The employee told police he did not know the sender of the message or why he received it. He decided to report the incident after his supervisor advised him to do so.

The message read: "This message is simply a reminder of the crime you are to commit on December 6th at 9:00a.m. You should have carefully read over your mission plan and memorized all relevant information in order to carry out your mission. Remember, do not bring materials with you related to the crime and maintain your innocence at all times. Good luck. Dispose of this message once understood," reports stated.

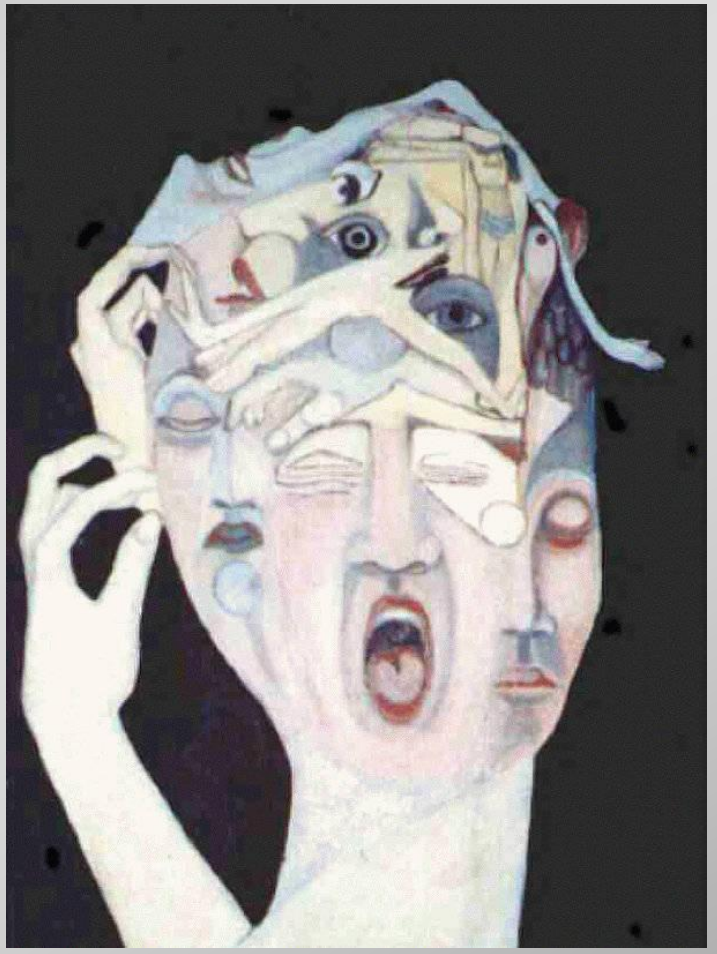
ARTICLES
Grad students may quit over tuition hike
Bike riders dodge some road rules
Eastside tech park to expand with hotel, golf course, offices
On the Spot
Art Briefs
Policebeat
CatCalls

Results of Mock Crime Brainwave Procedure

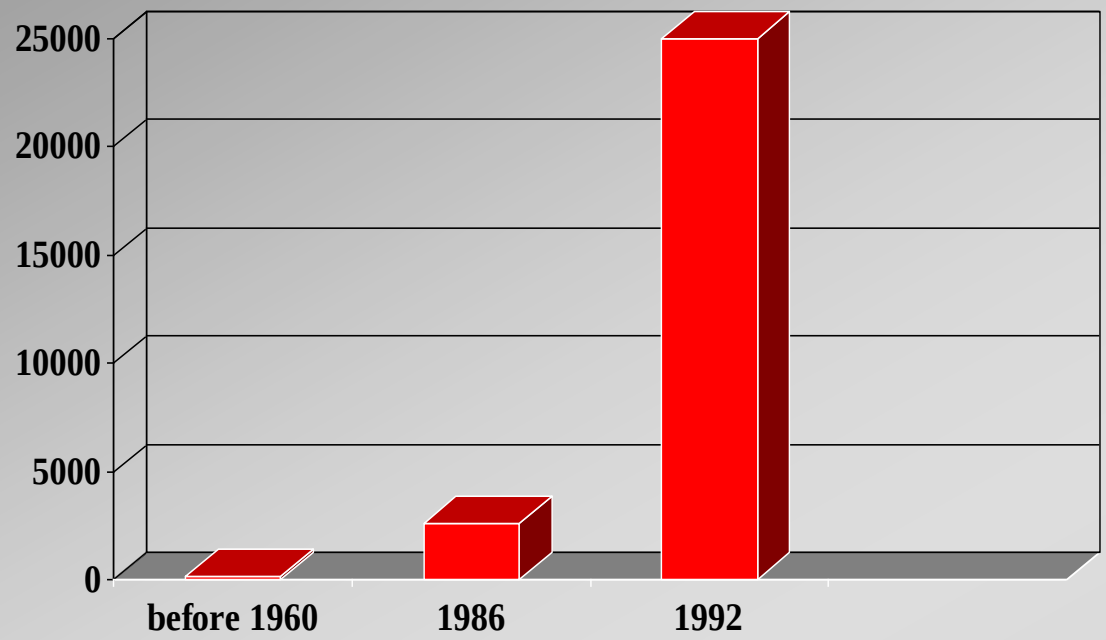
Group	N	Verdict	
		Guilty	Innocent
Guilty	15	47%	53%
Guilty (countermeasure)	45	17%	83%
Innocent	15	6%	94%

Note: Using Bootstrapping approach, Guilty detection drops to 27%, but innocent subjects classified correctly in 100% of cases. Allows indeterminate outcomes

ERPs and DID



Increasing Prevalence of DID

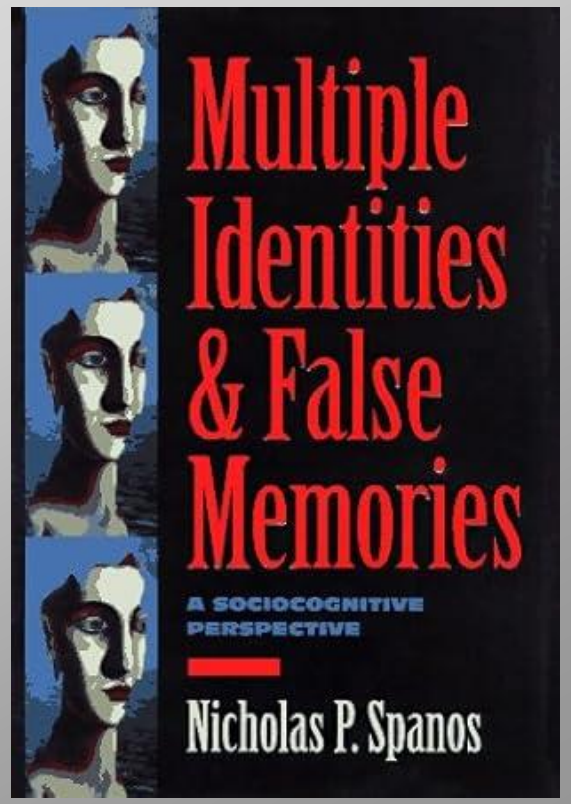


DSM-5 claims 1.5%!

Primarily a North American phenomenon

Perspectives on the Genesis of DID

- Post-traumatic Model (e.g. Gleaves, 1996)
- Socio-cognitive Model (Spanos, 1994, 1996)



Studies of Inter-identity Amnesia

Authors	Amnesia	Transfer of memory
Ludwig et al. (1972) N=1	◆ Recall of Paired Associates	◆ Facilitation of learning by subsequent identity ◆ Shock Conditioning
Dick-Barnes et al. (1987) N=1		◆ Paired Associates
Nissen et al. (1988) N=1	◆ Simple word recognition ◆ No facilitation recalling details of stories heard by other identity ◆ Experience of another identity did not affect word stem completion ◆ Interpretation of ambiguous texts and sentences	◆ Forced-choice facial recognition ◆ Repetition priming enhanced identification of briefly-presented masked words ◆ Word-fragment completion ◆ Sequence learning ◆ Impaired learning of re-paired paired associates

From Allen & Iacono, *PPPL*, 2001

Studies of Inter-identity Amnesia

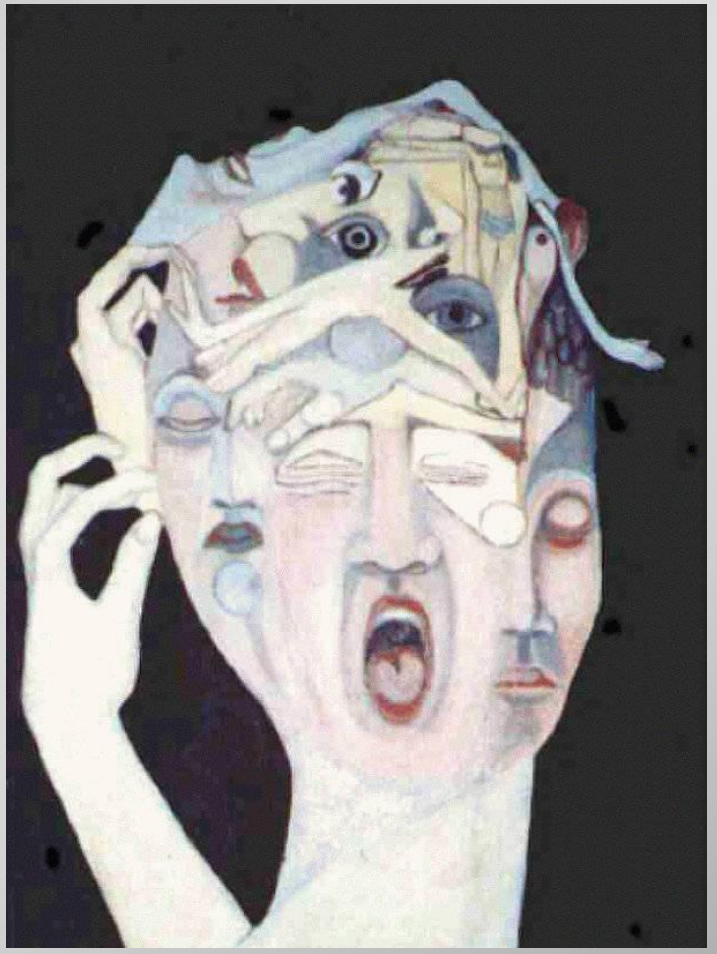
Authors	Amnesia	Transfer of memory
Eich et al (1997a, 1997b) N=9	Free Recall of words Experience of another identity did not affect word stem completion	Picture fragment completion facilitated by other-identity exposure (note that simulators do show amnesia on this task)
Silberman et al. (1985) N=9		Unable to "compartmentalize," and confused which identity had learned which words
Peters et al. (1998) N=4	Generally poor free recall of words	Some free recall of words (2/4) Recogntion (3/4) Word stem completion (3/4)
Allen & Movius (2000) N=4	Direct Assessments Poor Recall Generally Poor Recognition	Indirect Assessments RT and Errors ERPs

From Allen & Iacono, *PPPL*, 2001

Interpretations

- Nissen et al, Eich et al:
  - Transfer represents implicit memory
  - Indirect memory assessment is a necessary but not sufficient condition to see transfer across personalities
- Parsimonious Alternative (Allen & Iacono, 2001):
  - Direct inquiries about memory generally produce data consistent with amnesia
  - Indirect inquiries are less obviously memory tests, and often show transfer to memory across personalities
- Therefore need objective measures of memory: ERPs?

ERPs and DID



Procedure

- Identity A
  - Learn List A
  - Recognition Test Vs Distractors
- Switch to Identity B
- Identity B
  - Learn List B
  - Recognition Test with ERPs
    - “A” Words
    - “B” Words
    - Distractors

The DID Study

- Four patients meeting DSM-IV criteria for DID
  - Assessed with SCID-D
- All females age 39-51
- All had some college education
- All had history of other disorders (by self report)
- All divorced or separated
- Number of identities: 4-13
- DES range 47-91 (max is 100, >30 clinical range)
- MMSE range 28-30

Allen & Movius, *Int J Psychophysiology*, 2000

Demographic, diagnostic, and clinical information for DID Participants

M02

Demographics

- P.K. 39 y.o. female
- 2 years college
- divorced x 4
- unemployed x 2 years
- DES score = 70
- MMSE = 29

Diagnostic history

- history of substance abuse
- current meds = prozac, melaril
- diagnosed during course of substance-abuse treatment circa 1988, but reports symptoms have been present since at least teen years

Diagnostically Relevant Symptoms

- reports at least 10 identities
- daily gaps in memory/ missing time
- has found unfamiliar clothes in closet
- has found furniture re-arranged without knowledge
- describes internal dialogues between identities

M03

Demographics

- M.C. 36 y.o. female
- 2 years college
- separated from only marriage
- unemployed x 2 years; now student
- DES score = 47
- MMSE = 29

Diagnostic history

- history of eating disorder
- current meds = clonapin, wellbutrin, synthroid
- diagnosed 1991, but reports symptoms date back to at least teen years

Diagnostically Relevant Symptoms

- reports at least 13 identities
- daily gaps in memory/ missing time
- describes dramatic changes in abilities (e.g. artistic and computer work)
- reports age-regression experiences
- describes internal dialogues between identities

M04

Demographics

- M.D. 40 y.o. female
- 2 years college
- divorced
- employed 5 years
- DES score = 91
- MMSE = 28

Diagnostic history

- no history of substance abuse
- meds=clonapin, zoloft, promazine
- history of harm to self, hospitalizations
- in therapy on/off since 1983
- reports symptoms present since early childhood

Diagnostically Relevant Symptoms

- reports at least 4 identities
- daily gaps in memory/ missing time
- distant travel without knowing why
- has been called other names by people who insist they know her
- has found clothes, jewelry, furniture she did not remember buying
- describes changes in handwriting during journal entries

M05

Demographics

- A.J. 51 y.o. female
- 2 years of college
- divorced, widowed
- unemployed x 3 years
- DES score = 65
- MMSE = 30

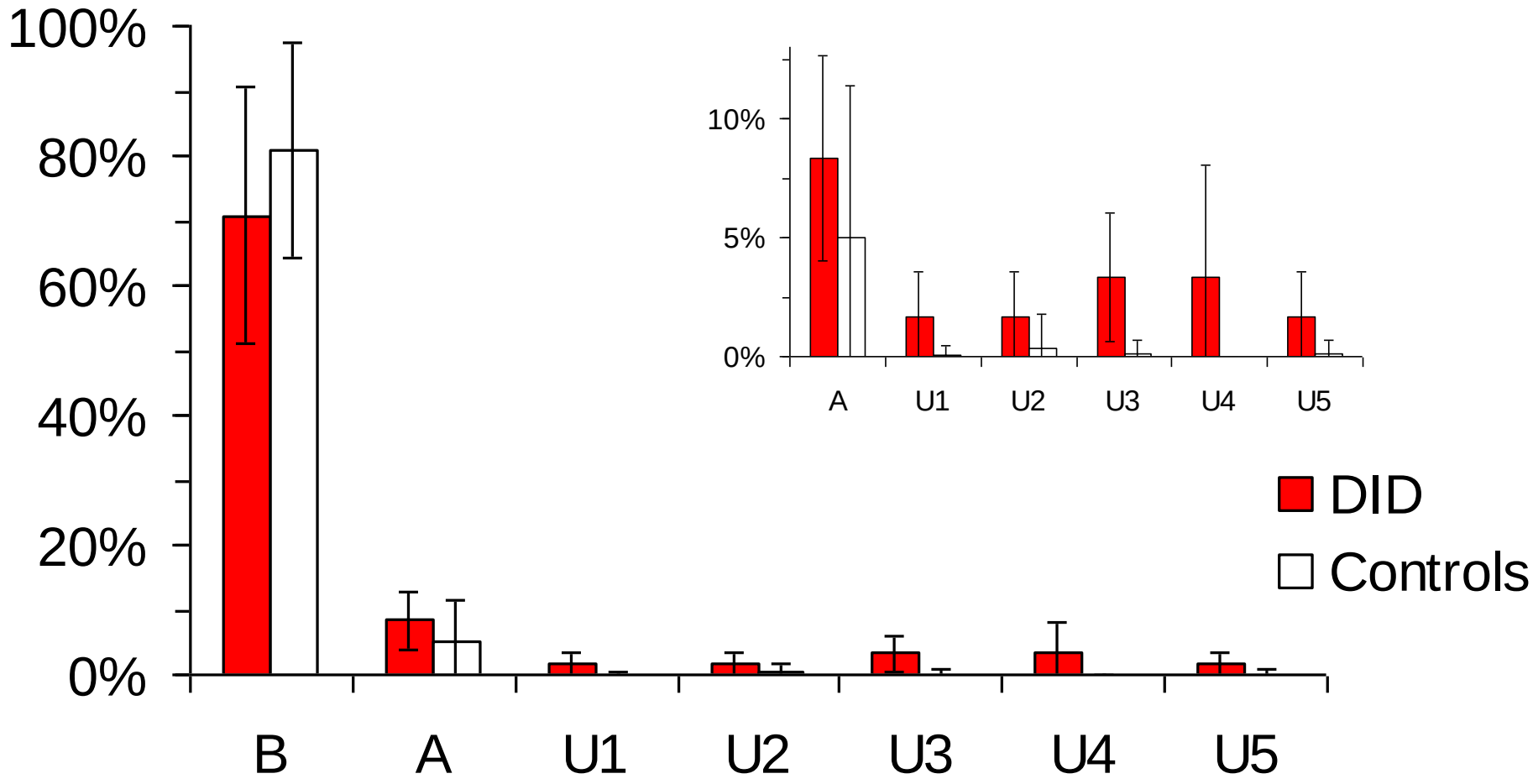
Diagnostic history

- "conversion reaction" 3 years ago after seizures, blindness, paralysis
- subsequent diagnosis of DID
- history of hositpalizations, suicide attempts (earliest at age 6)
- current meds = effexor, synthroid

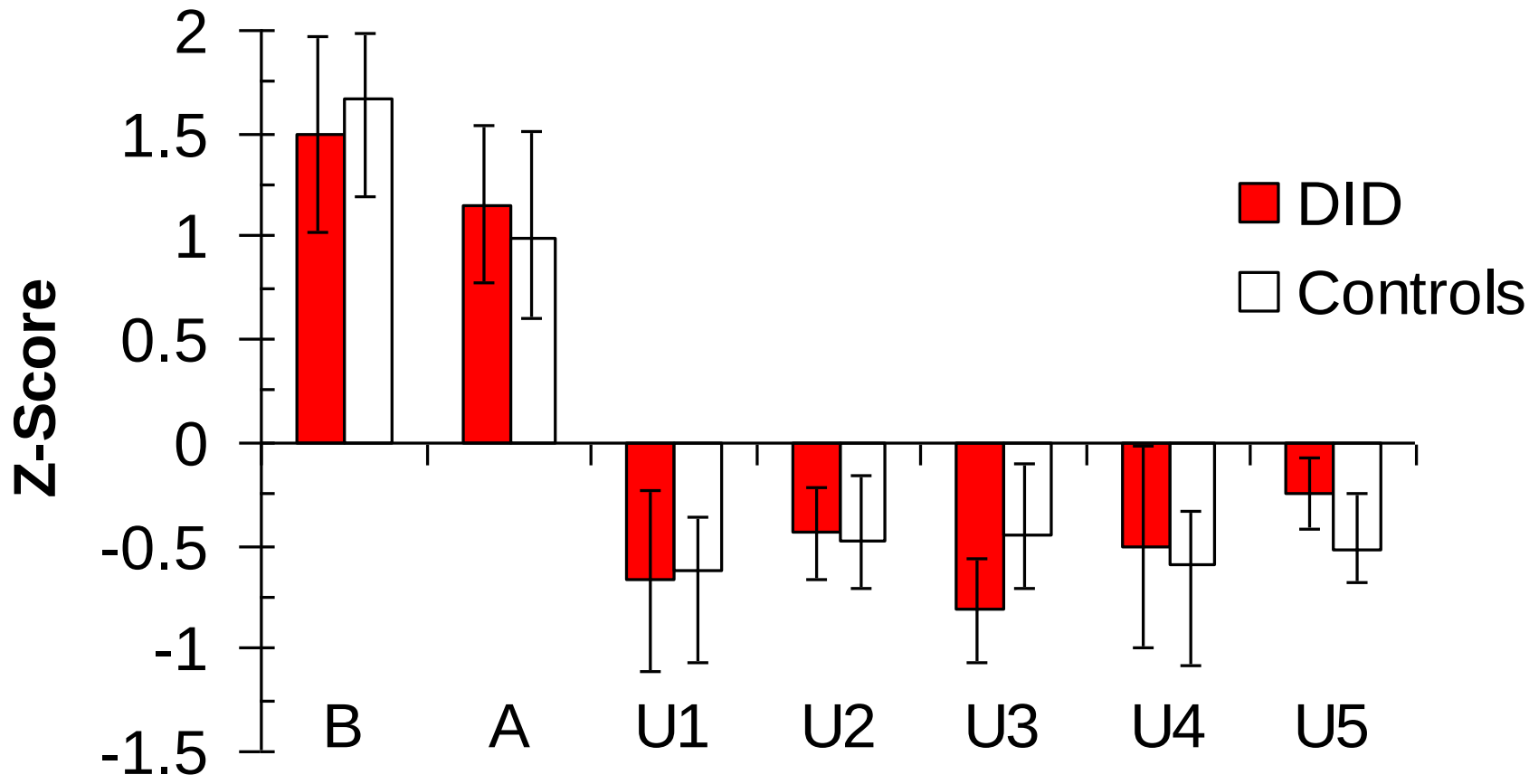
Diagnostically Relevant Symptoms

- reports at least 6 identities, one consistent alter throughout high school, and five now
- daily gaps in memory/ missing time
- reports internal dialogues between identities
- reports forgetting how to dress self, brush teeth (when a child identity)
- reports switching under duress, especially during family conflicts
- reports memories of ritual abuse

Behavioral Responses

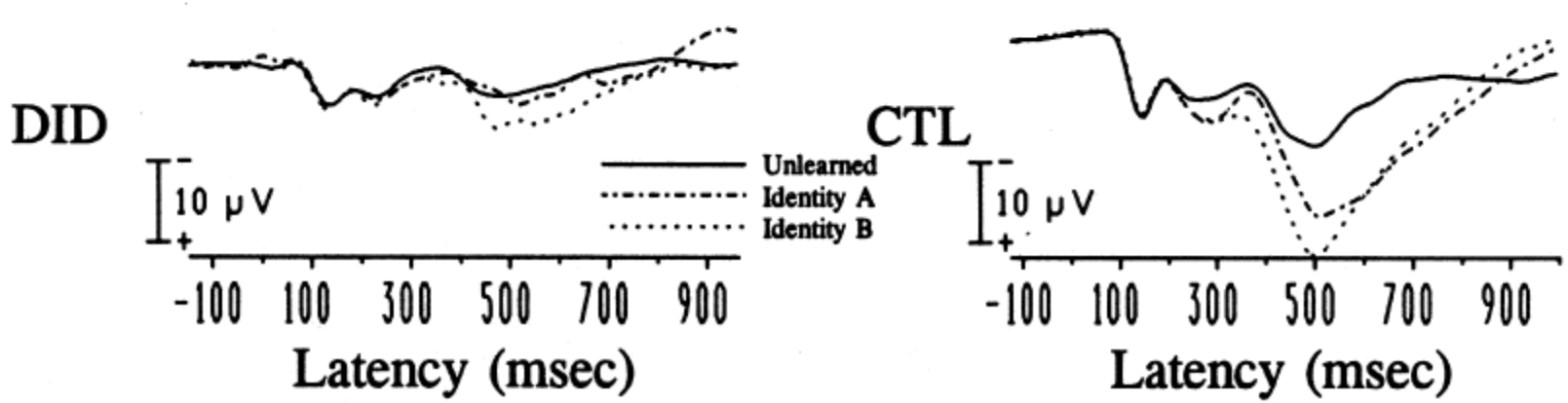


Reaction Time



Bayesian Combination of Behavioral Indicators

ID	Identity B	Identity A	U1	U2	U3	U4	U5
M02	1.00	1.00	0.01	0.01	0.01	0.01	0.01
M03	1.00	1.00	0.01	0.01	1.00	0.01	0.01
M04	1.00	1.00	0.01	0.01	0.01	0.01	0.01
M05	1.00	1.00	0.01	0.01	0.01	1.00	0.01


DID
10 μV
Unlearned
Identity A
Identity B
-100 100 300 500 700 900
Latency (msec)
CTL
10 μV
-100 100 300 500 700 900
Latency (msec)

Bayesian Combination of ERP Indicators

ID	Identity B	Identity A	U1	U2	U3	U4	U5
M02	0.98	1.00	0.00	0.87	0.19	0.00	0.00
M03	1.00	0.98	0.00	0.00	0.56	0.01	0.00
M04	1.00	0.98	0.00	0.13	0.00	0.00	0.00
M05	1.00	0.98	0.00	0.00	0.98	0.00	0.00

Amnesia in DID?

- Evidence for:
  - Subjects fail to recall Identity A's words
  - In general, deny recognition of Identity A's words
    - Although do acknowledge at rates above never seen words
- Evidence against:
  - RT and accuracy data suggest Identity A's words are familiar
  - ERP data suggest Identity A's words are familiar

Malingering or Implicit Memory?

- Malingering Measure Given to 2 of 4 subjects

- Forced-choice recognition
  - Explicit Probes: Words learned by Identity A
  - Incidental Probes: Words seen as distracters by Identity A

	Explicit Probes	Incidental Probes
M04	0%	50%
M05	33%	42%

Malingering or Implicit Memory?

- Malingering in one subject
  - Forced-choice malingering measures have adequate specificity, but poor sensitivity
  - Failure to detect malingering is therefore not conclusive
- RT and Recognition
  - DID patients, *as Identity B*, are influenced by Identity A's words in a manner almost identical to how college student controls are influenced by recently seen and recognized words.
- Two DID patients reported some "co-consciousness" yet responded as if amnestic as Identity B
  - Spanos (1994, 1996): DID as a socially constructed phenomenon
  - Symptoms are context bounded, goal-directed, social behavior produced in response to demand characteristics

The Nature of Amnesia in DID

- Implicit Memory?
  - Maybe in some cases, but seems less likely given the present findings
- Fabricated?
  - In same cases it would appear that the amnesia is fabricated
  - But we did not test all DID patients, nor even all pairs within these 4 DID patients
- Social Construction? (Spanos 1994, 1996)
  - Remains a possibility
  - So too does implicit memory?

ERPs and Affective Processing

- IAPS = International Affective Picture System
  - Pleasant, Neutral, Unpleasant
  - Vary in Arousal: Pleasant and Unpleasant tend to be more arousing
- Predict more significant stimuli produce larger P3

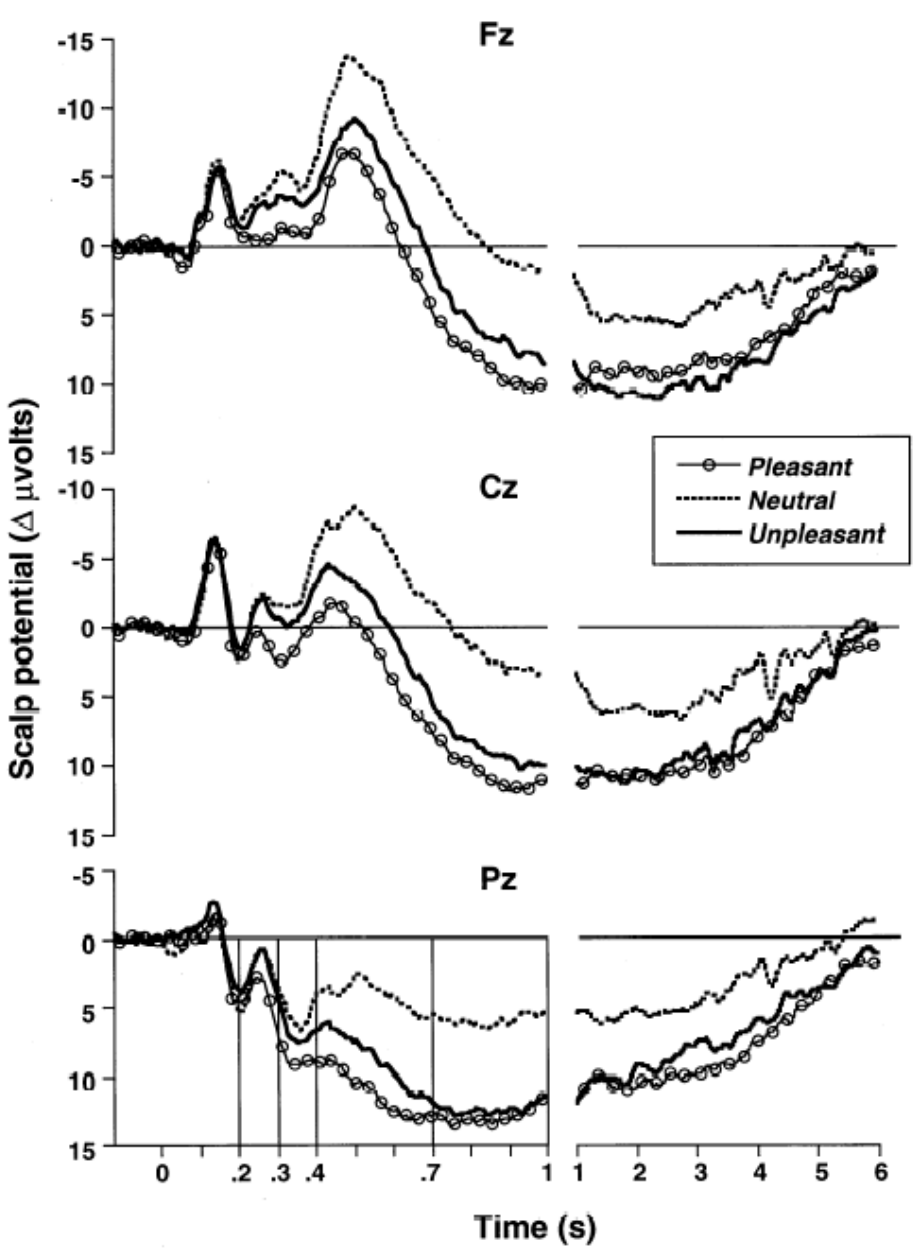


Fig. 1. Stimulus synchronized grand average ERP waveforms for Fz, Cz, and Pz electrodes during viewing of affective pictures, separately for each valence category (pleasant, neutral and unpleasant). The left panel illustrates the picture onset potentials on a finer time scale, and the vertical lines at Pz illustrate the time areas subjected to statistical analysis (i.e. 200–300, 300–400, 400–700, 700–1000 ms). The right panel shows the subsequent 5 s of slow potential change.

Long (6 sec)
Presentation Duration

Schupp et al (2000),
Psychophysiology

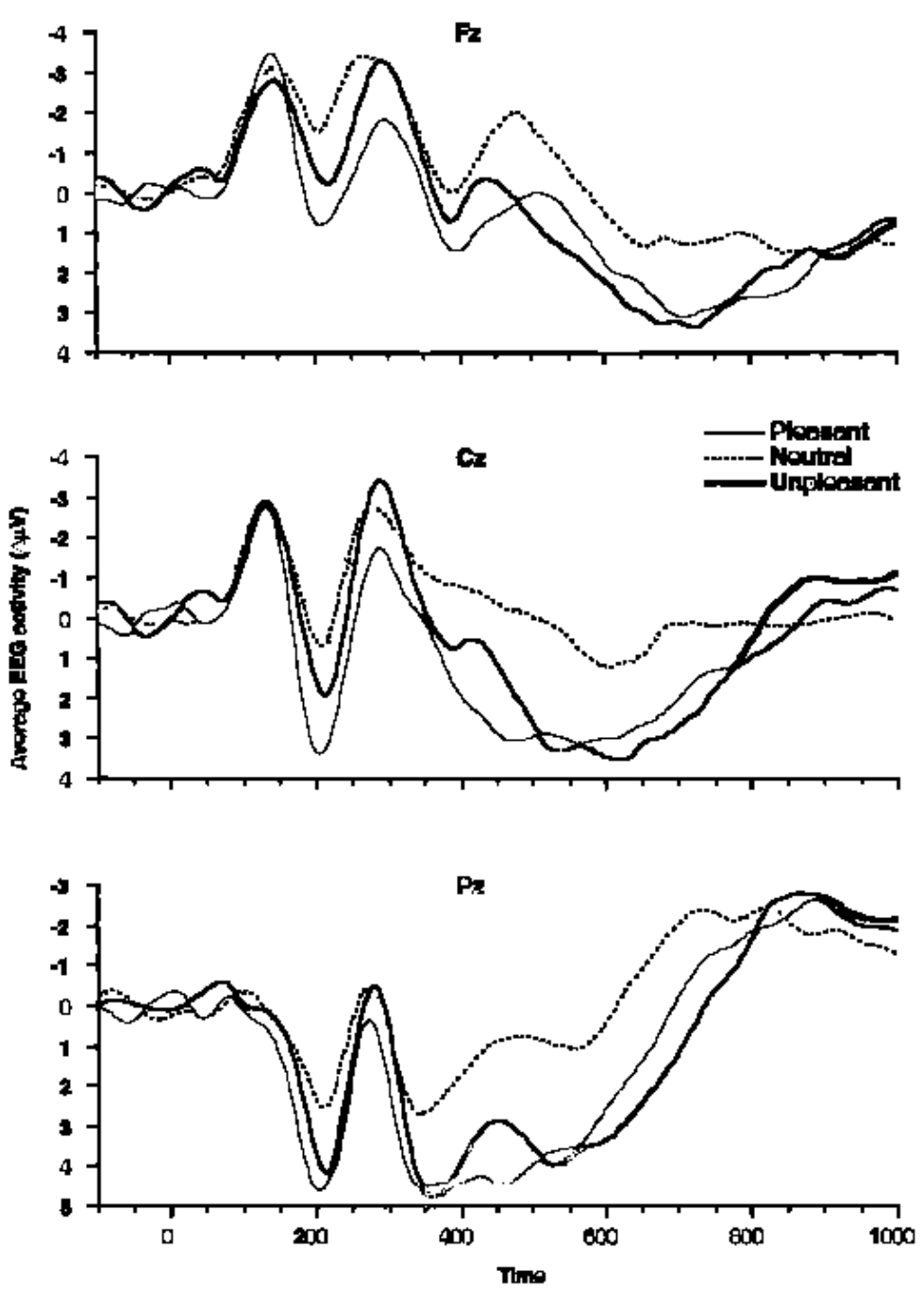


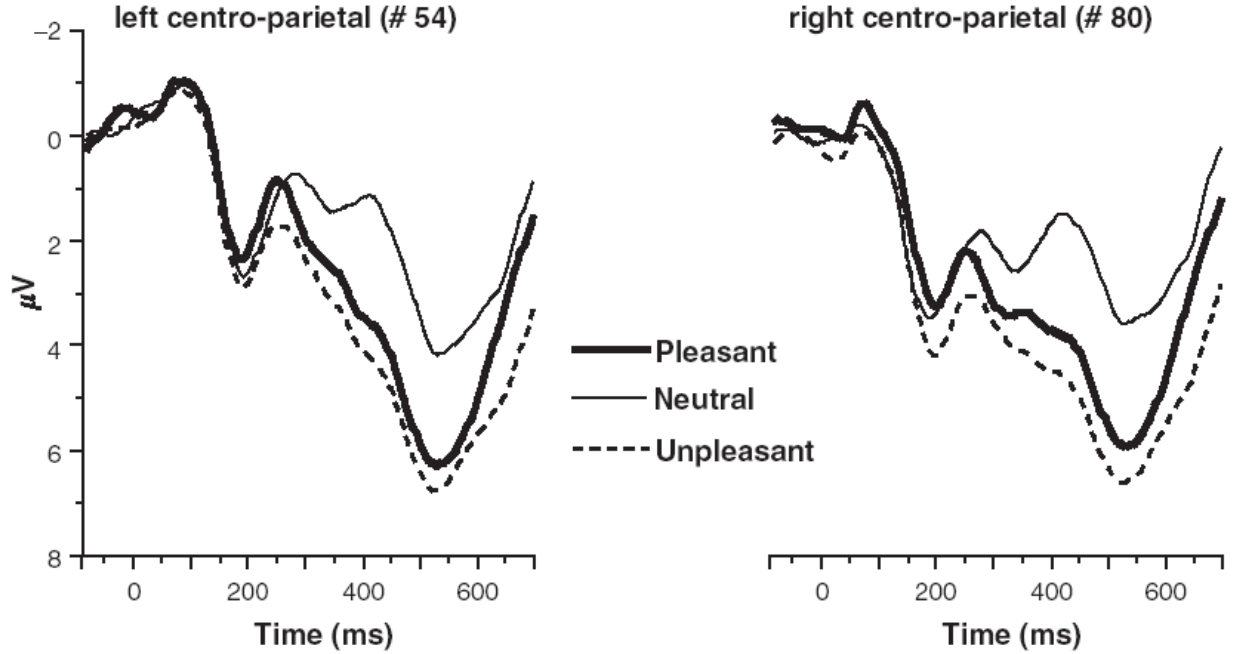
Figure 1. Picture onset synchronized grand-average event-related potential (ERP) waveforms for each valence category (pleasant, neutral, and unpleasant) from midline electrodes Fz, Cz, and Pz.

1.5 sec Presentation Duration

Cuthbert et al (2000), *Biological Psychology*

120 msec Presentation Duration

Schupp et al (2004), *Psychophysiology*



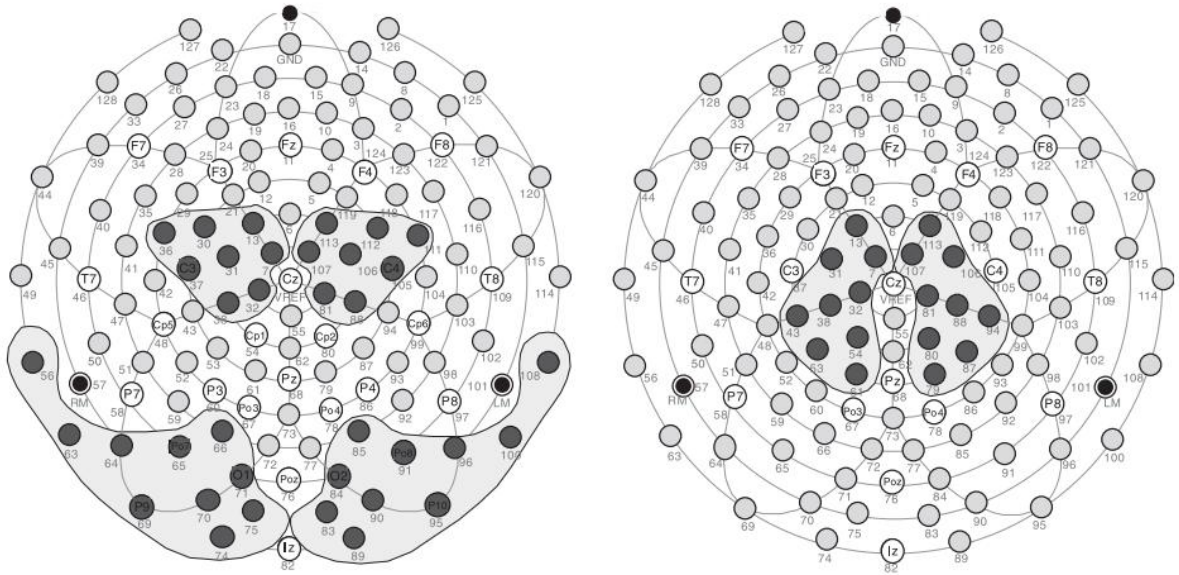


Figure 1. Sensor outline of the geodesic sensor net. The left and right panels illustrate the sensor clusters used to quantify the early (EPN) and late (LPP) selective ERP components, respectively.

ERPS and Implicit Affective Processing

- Ito & Cacioppo (2000) *JESP*
  - Evaluative Processing (positive vs negative)
  - Nonevaluative (people vs no-people)

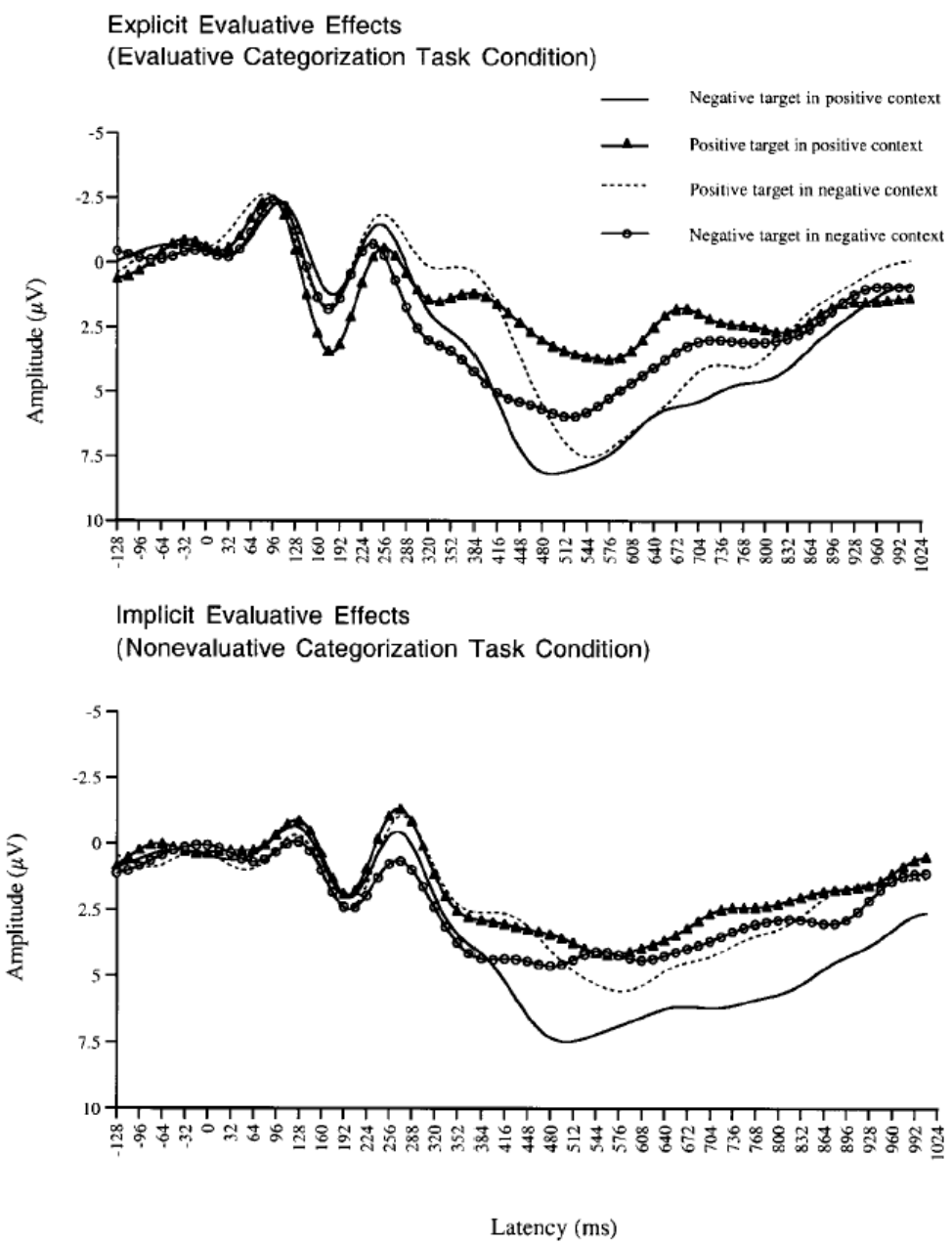


FIG. 2. Averaged event-related potential waveforms at electrode Pz as a function of target and context valence. The top panel depicts explicit evaluative categorization effects (data from participants in the evaluative task condition). The bottom panel depicts implicit evaluative categorization effects (data from participants in the nonevaluative task condition). The late-positive potential is the positive (downward) deflection peaking at approximately 450–550 ms.

Ito & Cacioppo (2000) *JESP*

N400 and Language

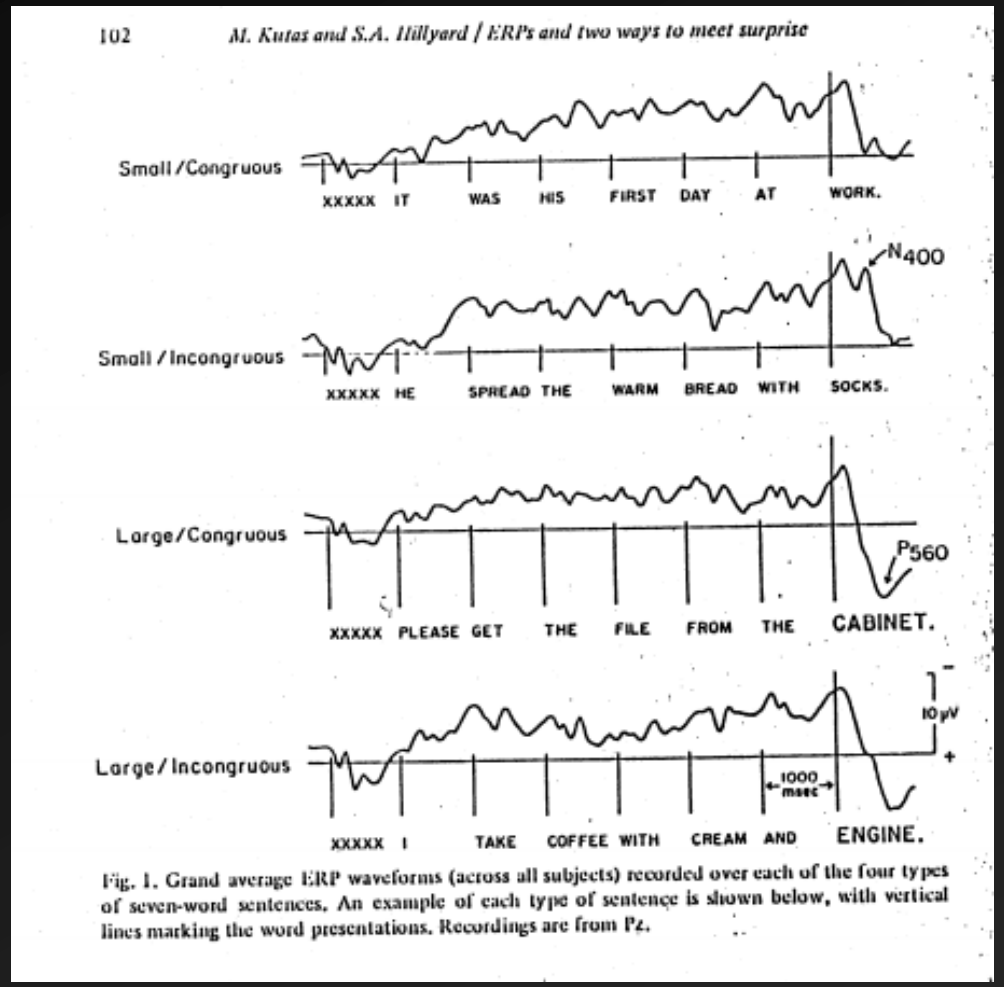
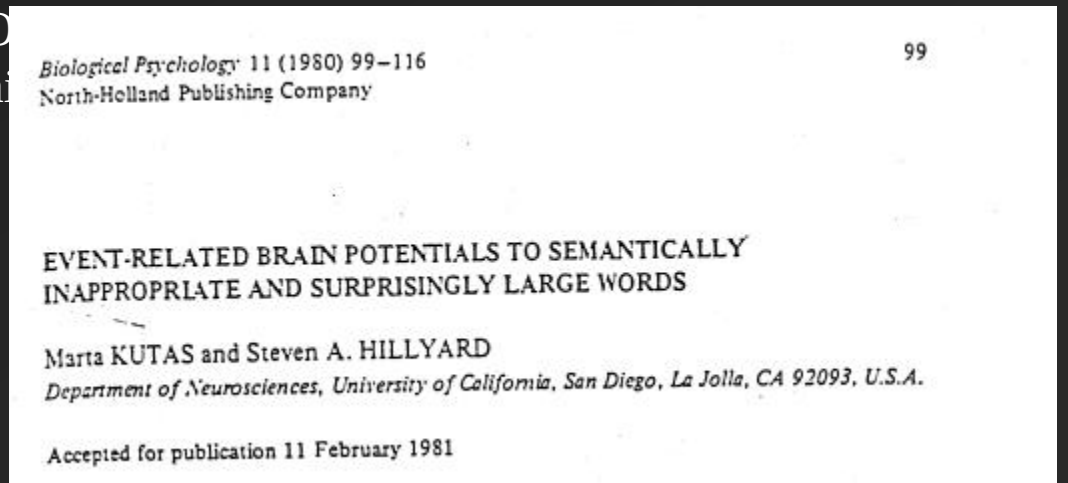


Fig. 1. Grand average ERP waveforms (across all subjects) recorded over each of the four types of seven-word sentences. An example of each type of sentence is shown below, with vertical lines marking the word presentations. Recordings are from Pz.

- Originally reported by Kutas & Hillyard, 1980.
- Semantic Incongruity is separable from other forms of deviations (e.g. large font)
  - N400 Semantic Deviation
  - P300 Physical Deviation
- Also seen in semantic differentiation tasks (Polich, 1985); APPLE, BANANA, ORANGE, MANGO, *TRUCK*
- NO
(whi



Biological Psychology 11 (1980) 99–116
North-Holland Publishing Company

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EVENT-RELATED BRAIN POTENTIALS TO SEMANTICALLY INAPPROPRIATE AND SURPRISINGLY LARGE WORDS

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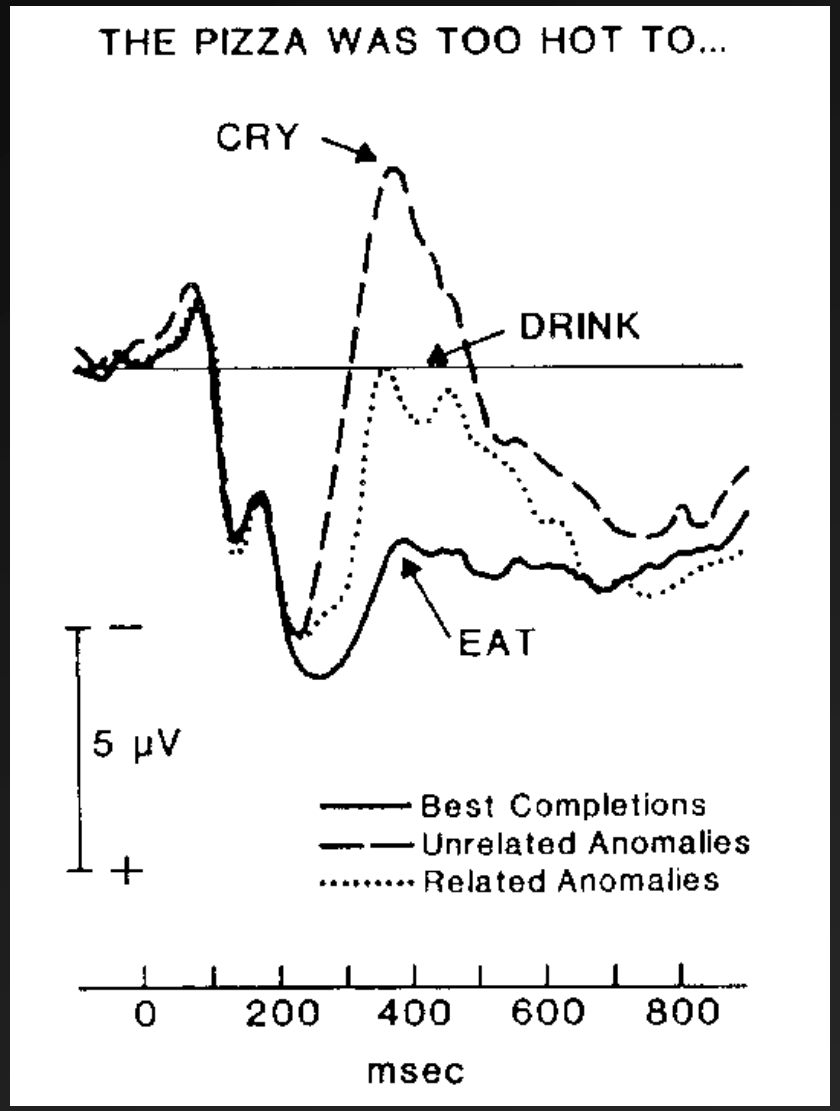
Accepted for publication 11 February 1981

N400 and Language



Sensitive to degree of semantic incongruity

Political Evaluations!

- Morris Squires et al. *Political Psychology* 2003

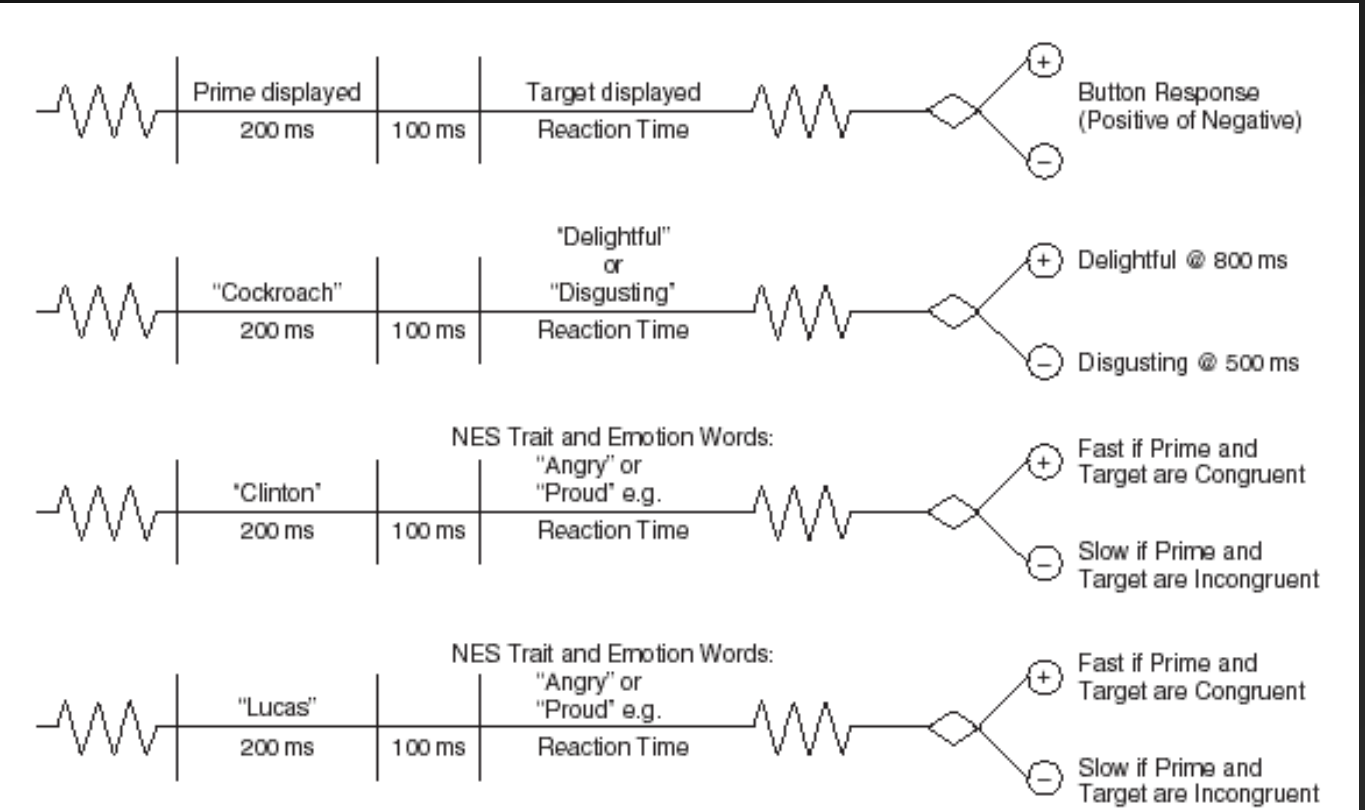


Figure 2. Attitude-priming paradigm and examples of its use.

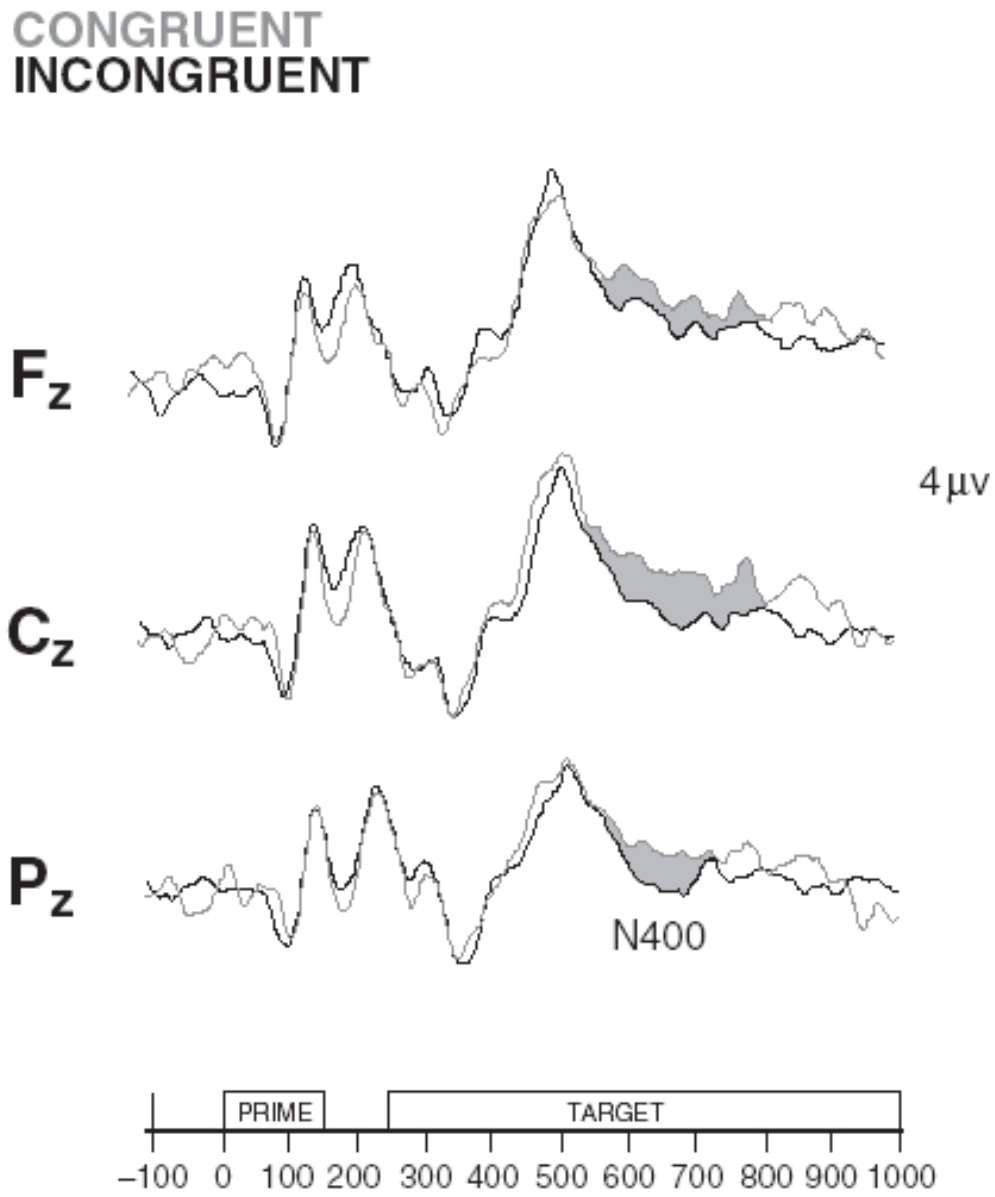
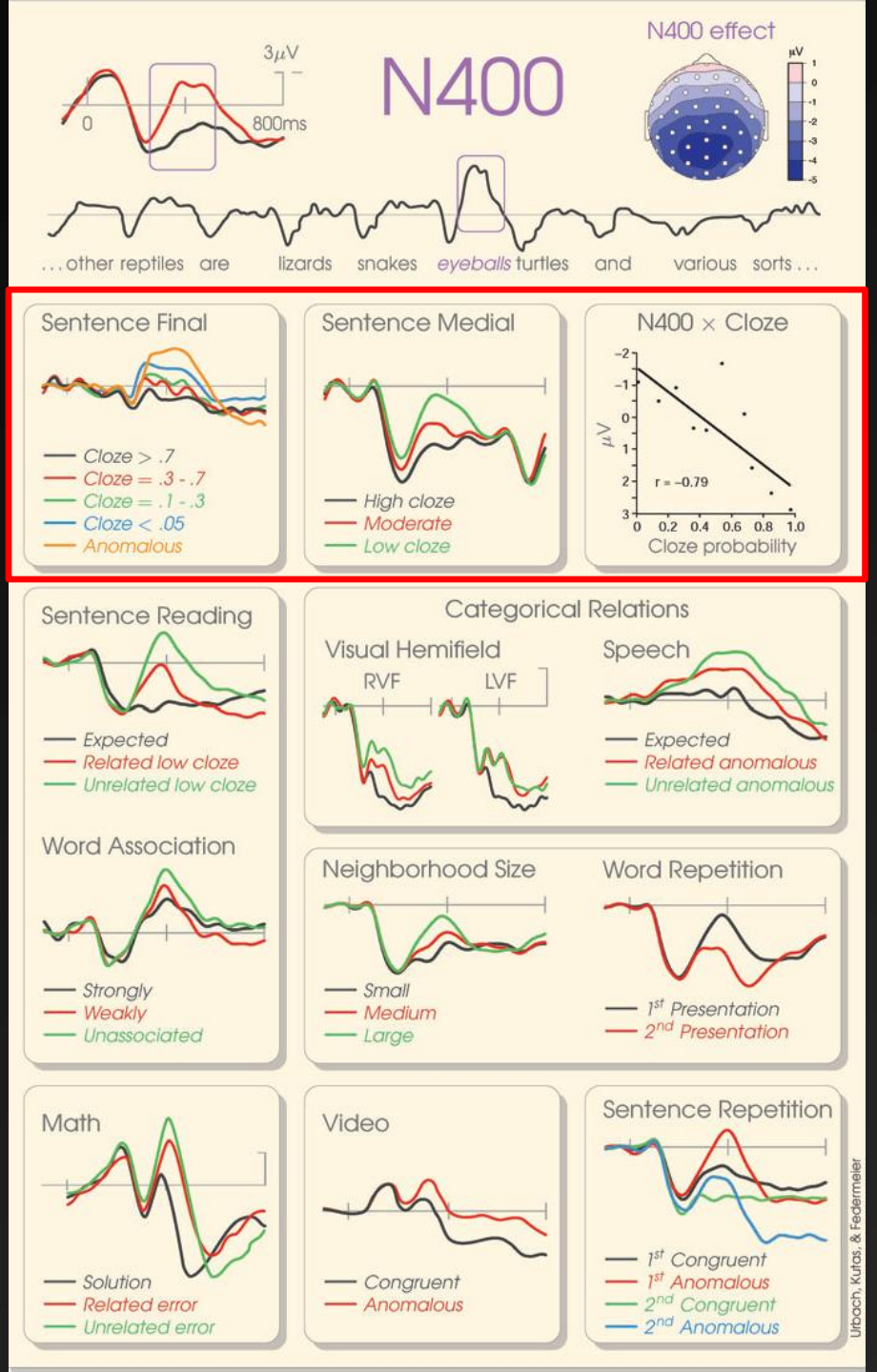


Figure 4. ERPs to congruent and incongruent prime/target pairs.

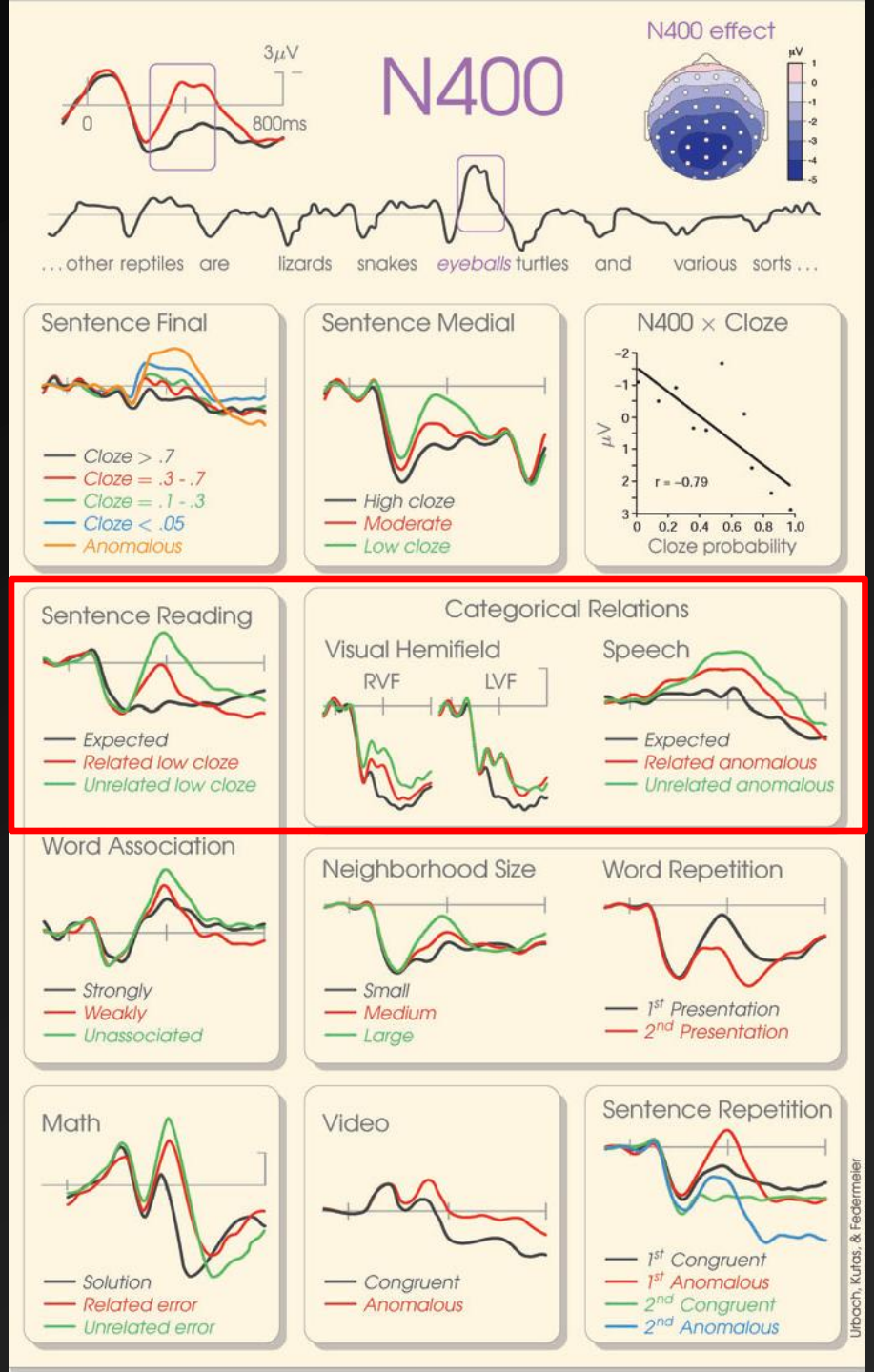
Congruent or incongruent defined based on idiographic data from pretest

Morris Squires et al. *Political Psychology* 2003



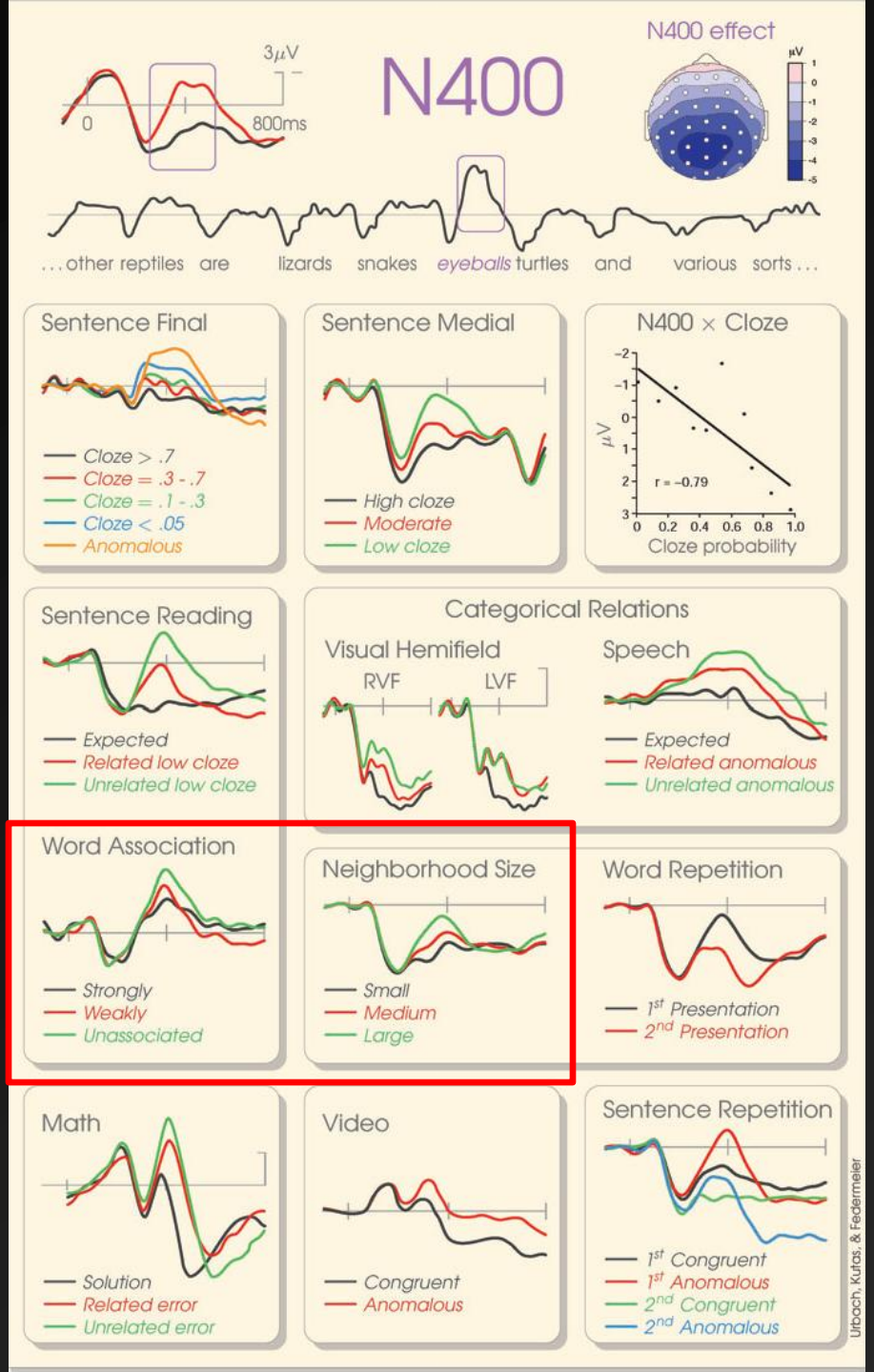
- Cloze probability: proportion of respondents supplying the word as continuation given preceding context
- N400 reflects unexpected word given the preceding context
- This is independent of degree of contextual constraint
- Larger N400
  - Low cloze, Contextual constraint high:
    - *The bill was due at the end of the hour*
  - Low cloze, Contextual constraint low:
    - *He was soothed by the gentle wind*
- *Smaller N400*
  - *The bill was due at the end of the month*

Kutas & Federmeier, 2011



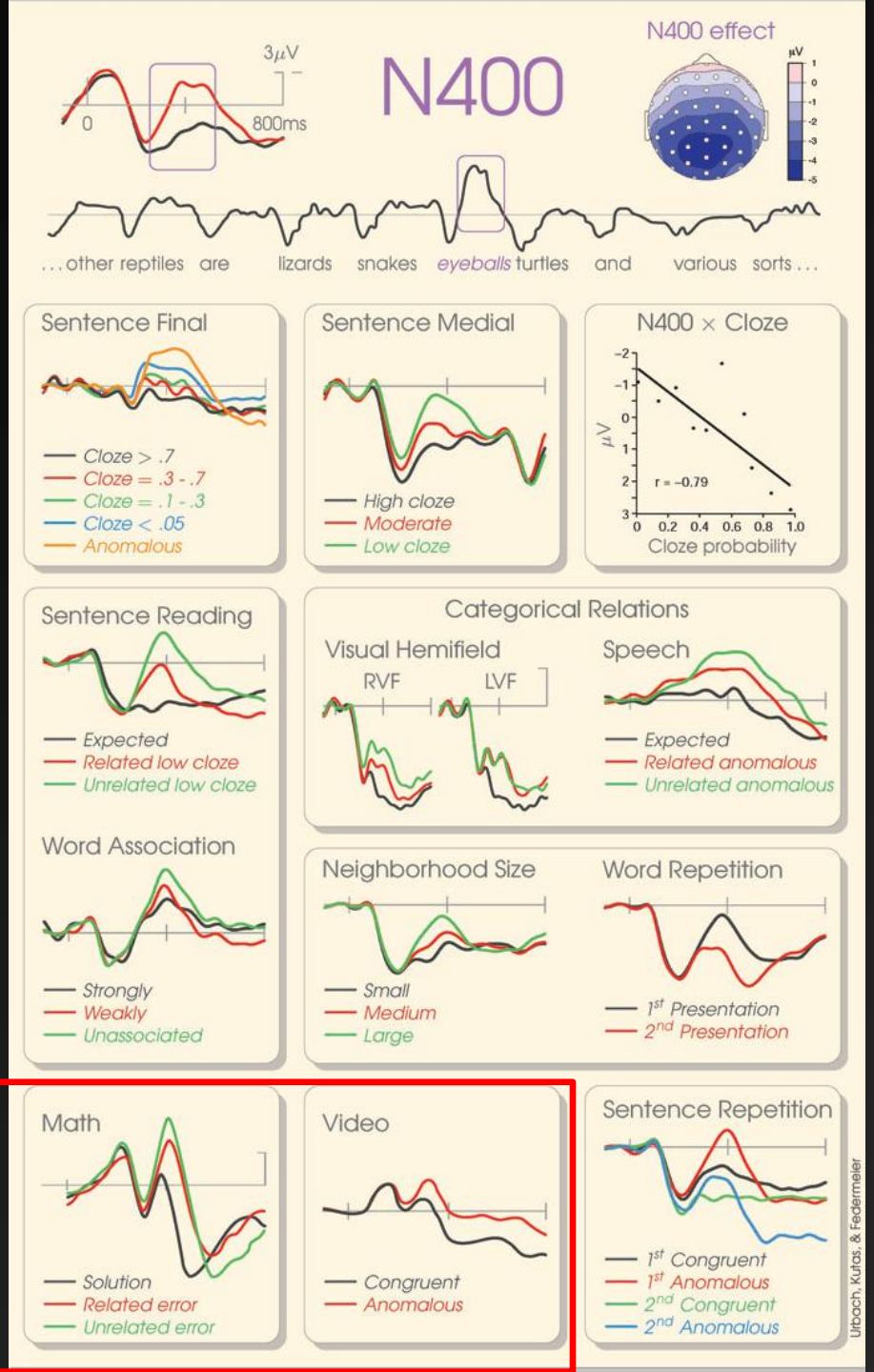
- Sentence completion
  - Best (expected) ending *small*
  - Unexpected but related *larger*
  - Unexpected and unrelated *largest*
- Categorical relations … sentence final word is:
  - an expected category exemplar
  - an unexpected, implausible exemplar from the same category as the expected one (related anomalous)
  - from a different category (unrelated anomalous)
- Note multiple modalities of effect, and graded effect in RVF (LH)

Kutas & Federmeier, 2011



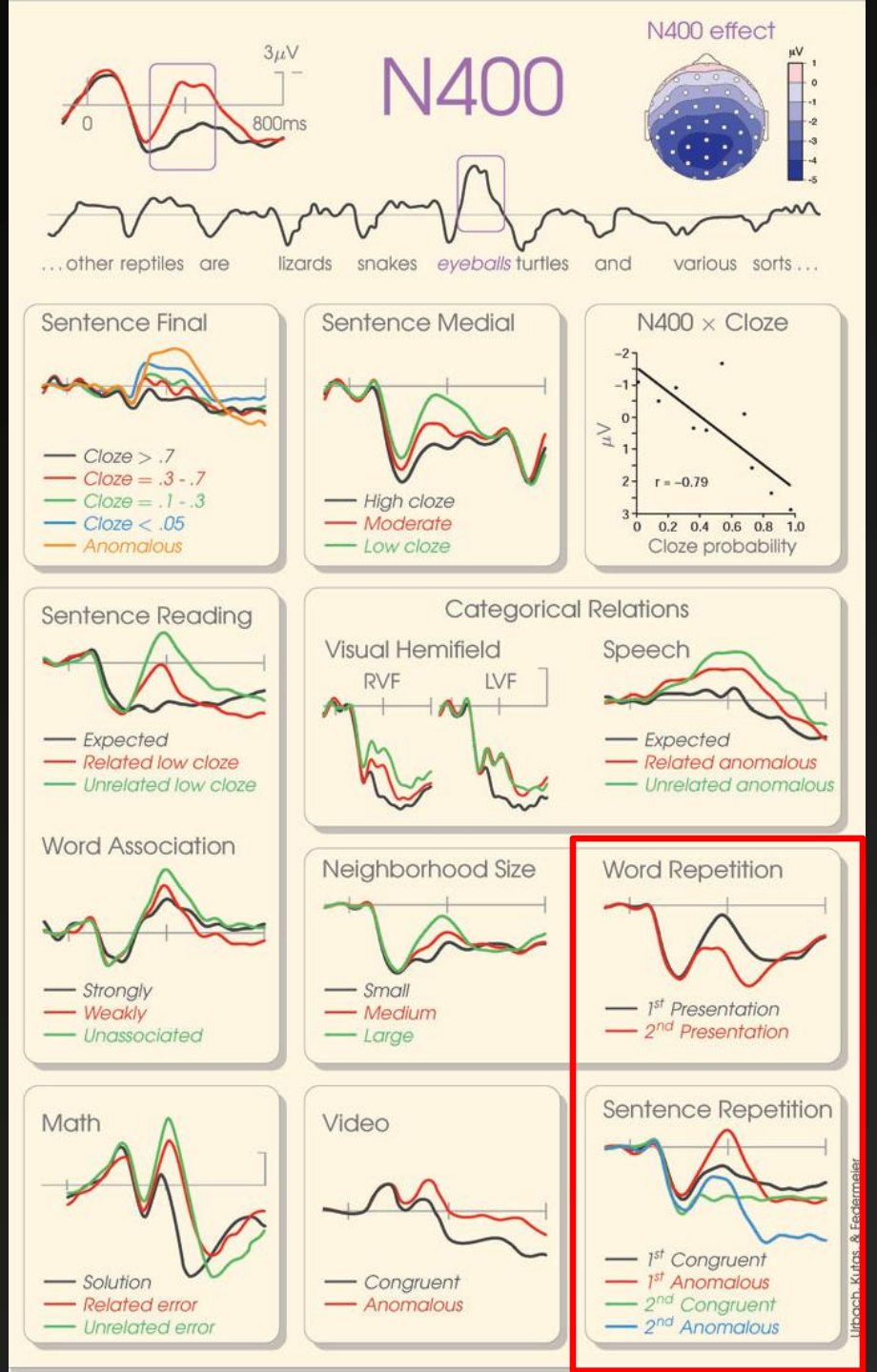
- Word Association, with second word in pair
  - Unrelated to first (*eat door*)
  - Weakly related to first (*eat spoon*)
  - Strongly related to first (*eat drink*)
- Orthographic neighborhood size (among a list of words, pseudowords, and acronyms)
  - Words that share all but one letter in common with particular word
  - Large ‘hood (e.g., slop) – *large N400*
  - Small ‘hood (e.g. draw) – *small N400*

Kutas & Federmeier, 2011



- Math: (e.g., 5 x 8 = ___)
  - Correct (40) *small*
  - Related (32, 24, 16) *small if close*
  - Unrelated (34, 26, 18) *large*
- Movement and Gestures
  - Typical actions (cutting bread with knife) = *small*
  - Purposeless, inappropriate, or impossible actions = *large*
    - *Cutting jewelry on plate with fork and knife*
    - *Cutting bread with saw*
  - N400 modulated by both:
    - appropriateness of object (e.g., screwdriver instead of key into keyhole)
    - features of motor act per se (e.g., orientation of object to keyhole)

Kutas & Federmeier, 2011



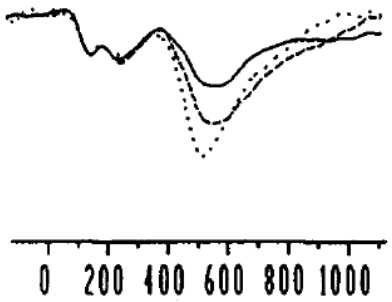
- Repetition effects
  - Repetition creates contextual familiarity, reduced processing demands
  - N400 thus useful in studying memory
  - Appears additive with incongruency effects

Kutas & Federmeier, 2011

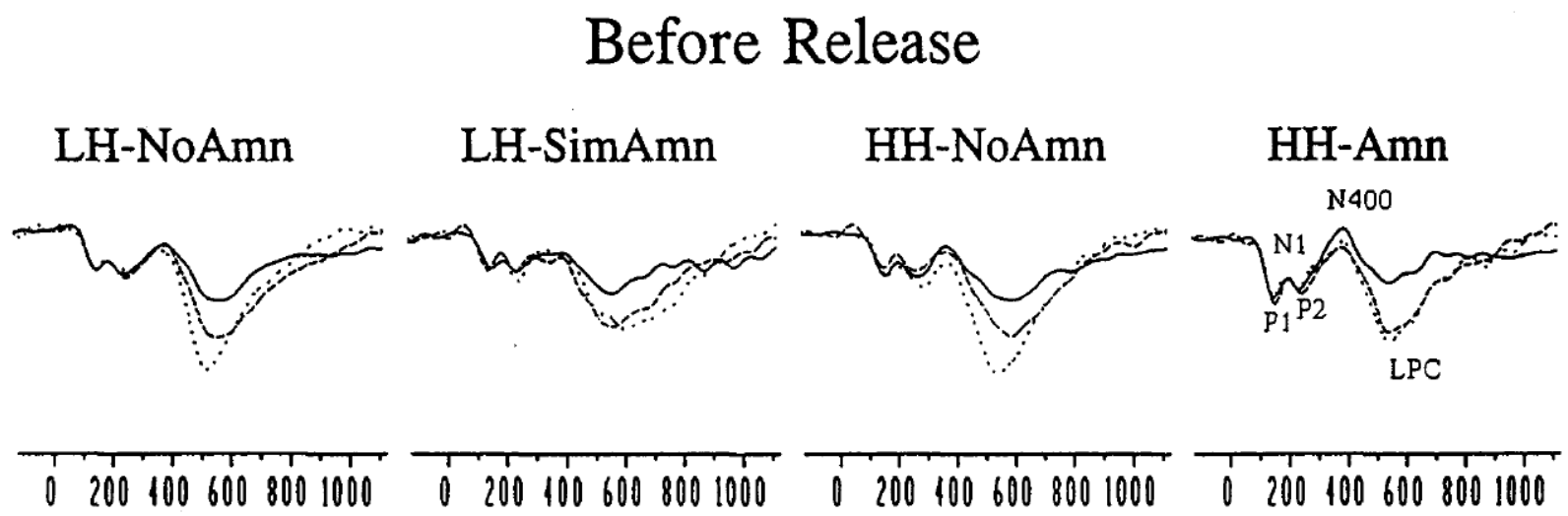
N400 – The Unexpected Hero!

Before Release

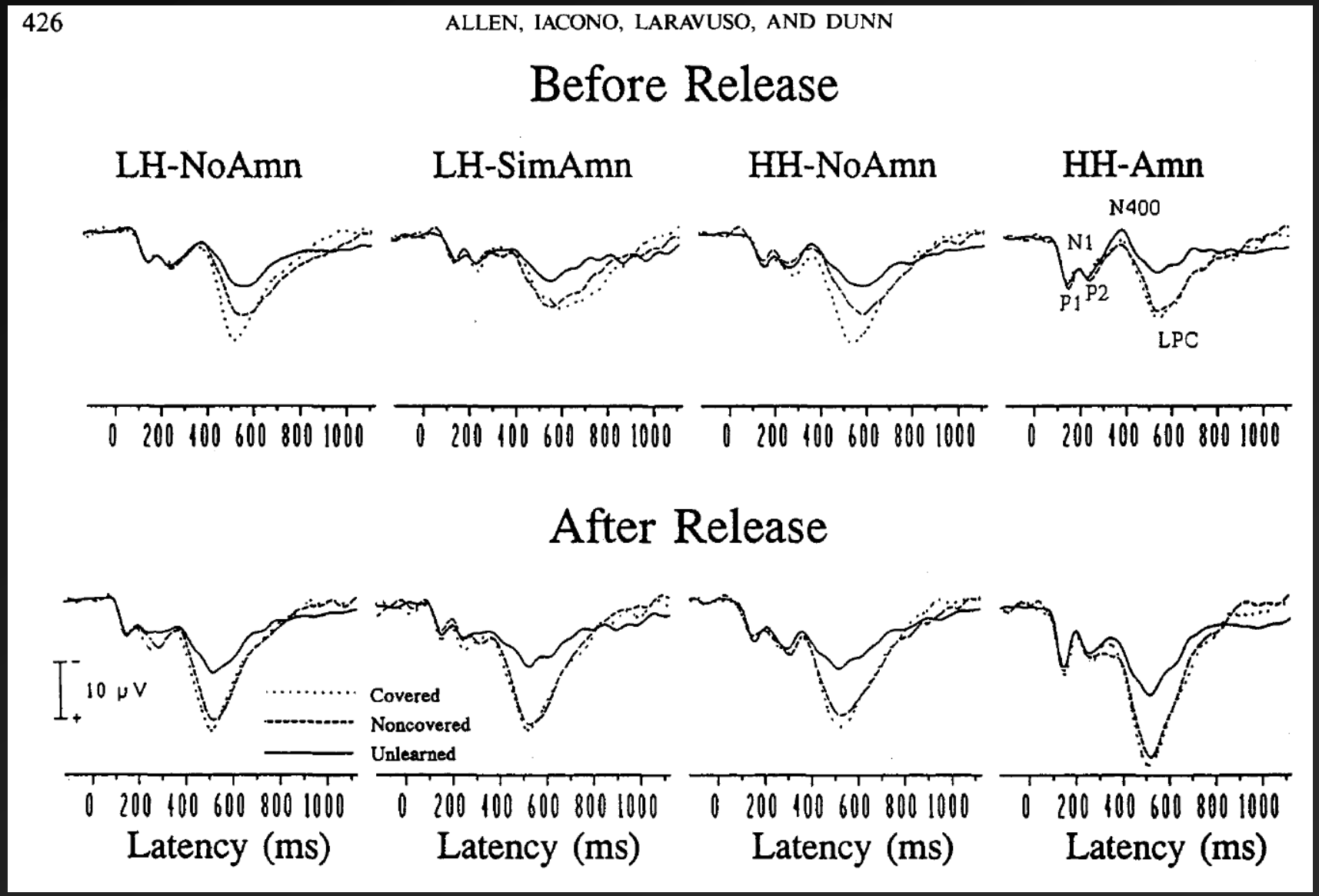
LH-NoAmn LH-SimAmn HH-NoAmn HH-Amn



N400 – The Unexpected Hero!



N400 – The Unexpected Hero!

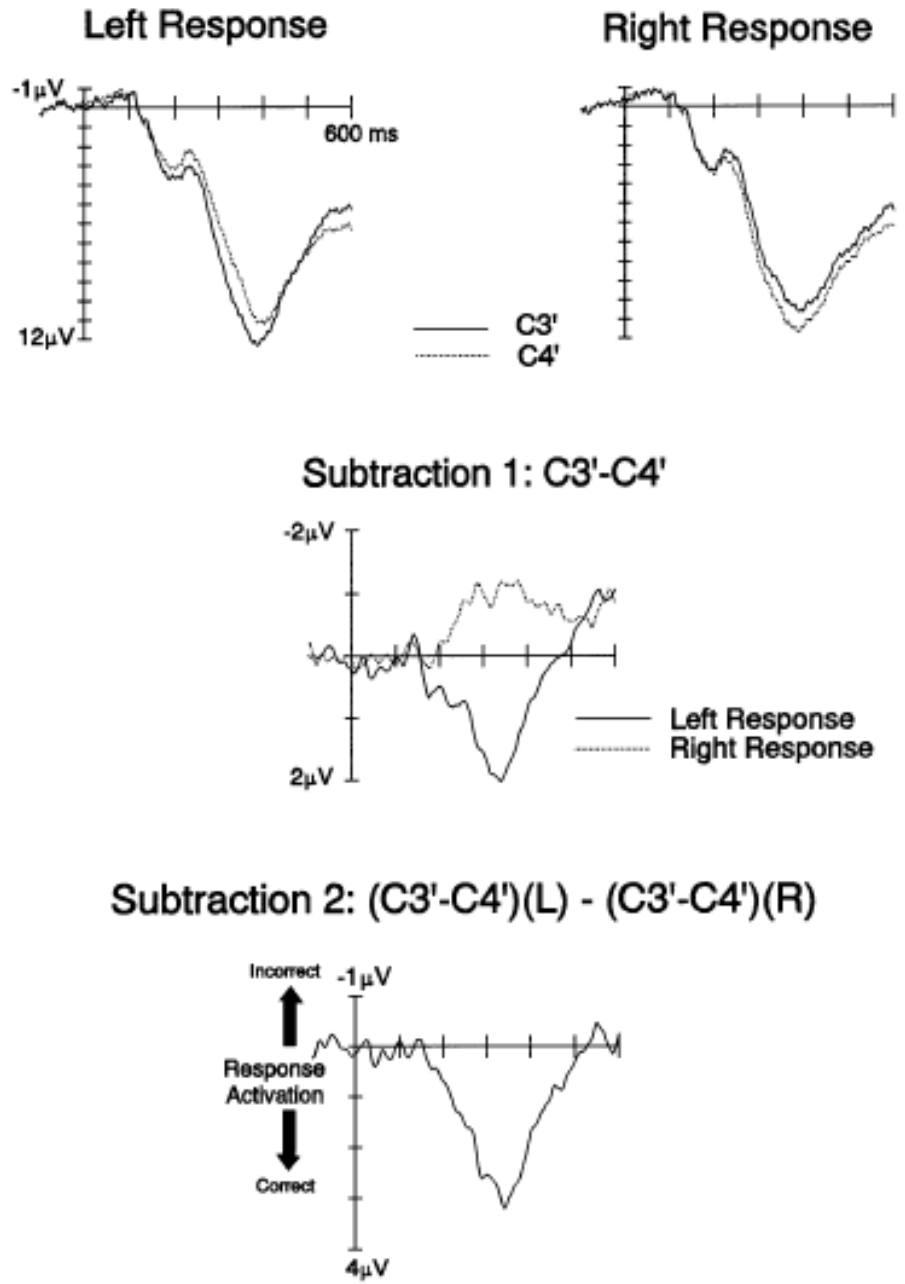


Response-locked potentials

- Lateralized Readiness Potential (LRP), a special case of movement-related potentials
- Error-related Negativity (ERN, aka N_E)

Eimer 1998, *Beh Res Methods*

Lateralized Readiness Potential



- LRP can be stimulus-locked or response-locked
- For stim-locked, latency is time between stimulus onset and LRP onset
- For rsps-locked latency is time between an LRP deflection and the overt response.

Figure 1. Computation of the lateralized readiness potential (LRP) with the double subtraction method on the basis of event-related brain potential (ERP) waveforms elicited at electrodes C3′ (left hemisphere) and C4′ (right hemisphere). Top panels: Grand-averaged ERP waveforms from 10 subjects elicited at C3′ (solid lines) and C4′ (dashed lines) in response to stimuli requiring a left-hand response (left side) and to stimuli requiring a right-hand response (right side). Middle panel: Difference waveforms resulting from subtracting the ERPs obtained at C4′ from the ERPs obtained at C3′ separately for left-hand responses (solid line) and right-hand responses (dashed line). Bottom panel: LRP waveform resulting from subtracting the C3′ − C4′ difference waveform for right-hand responses from the C3′ − C4′ difference waveform for left-hand responses. A downward-going (positive) deflection indicates an activation of the correct response; an upward-going (negative) deflection indicates an activation

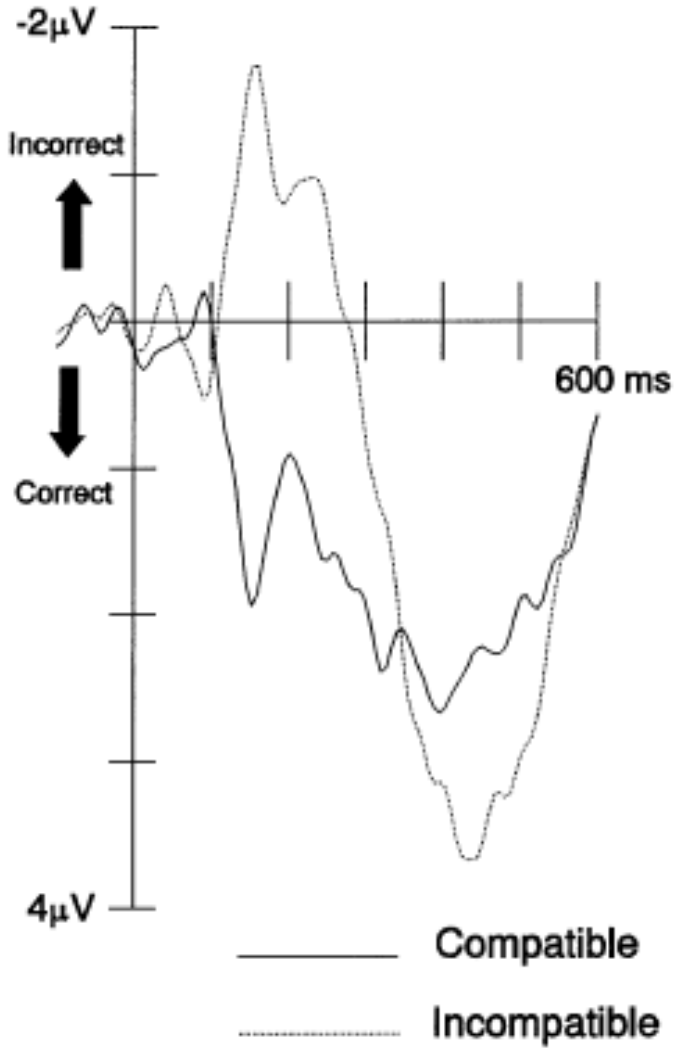
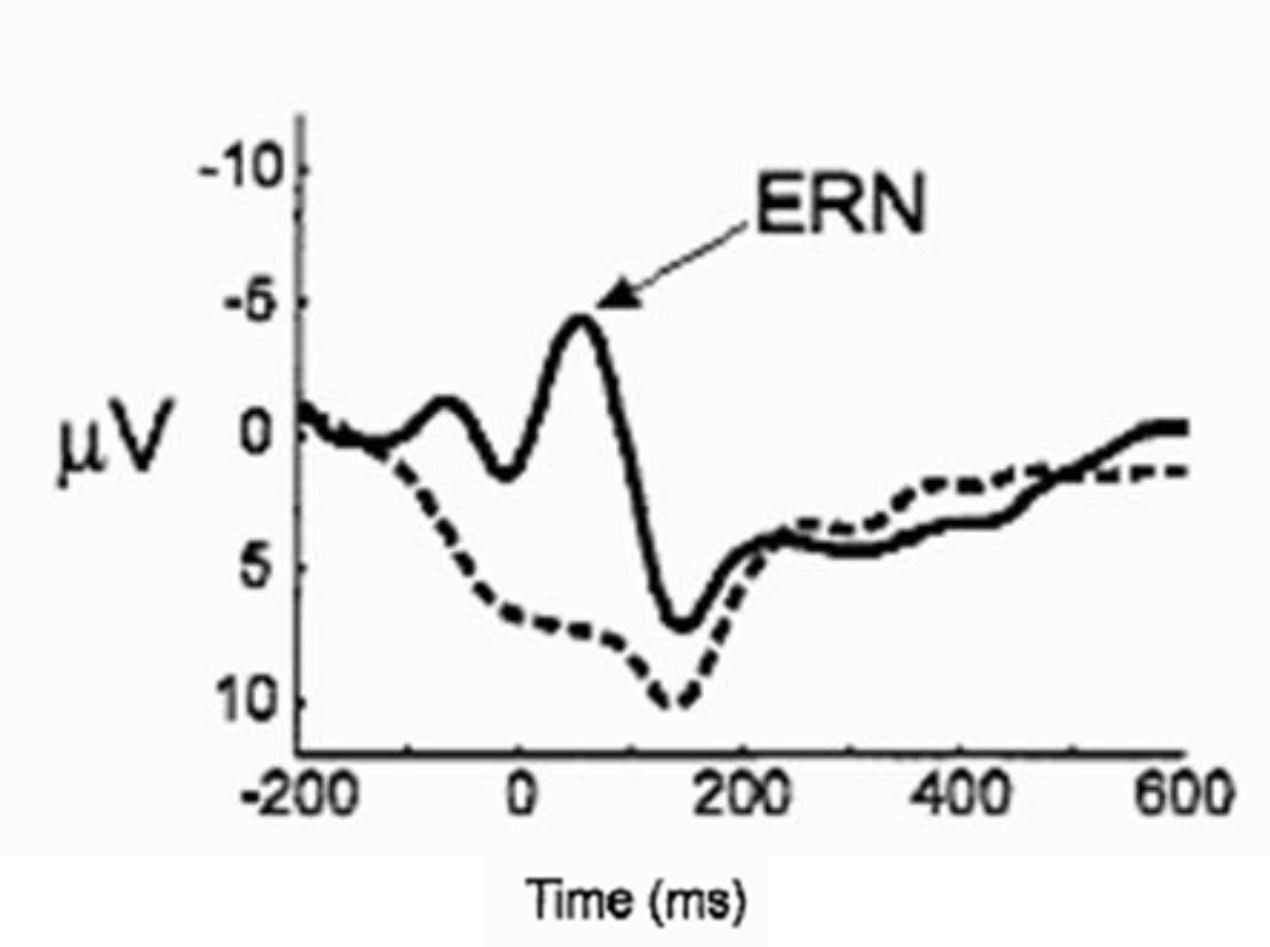


Figure 2. Top: Examples of stimulus displays in an experiment on spatial stimulus–response compatibility (Eimer, 1993, Experiment 1a) in which stimulus and response sides could either be compatible (left side) or incompatible (right side). Bottom: Grand-averaged LRP waveforms from 10 subjects, elicited in compatible trials (solid line) and in incompatible trials (dashed line).

Response conflict in the LRP

Eimer 1998, *Beh Res Methods*

The ERN

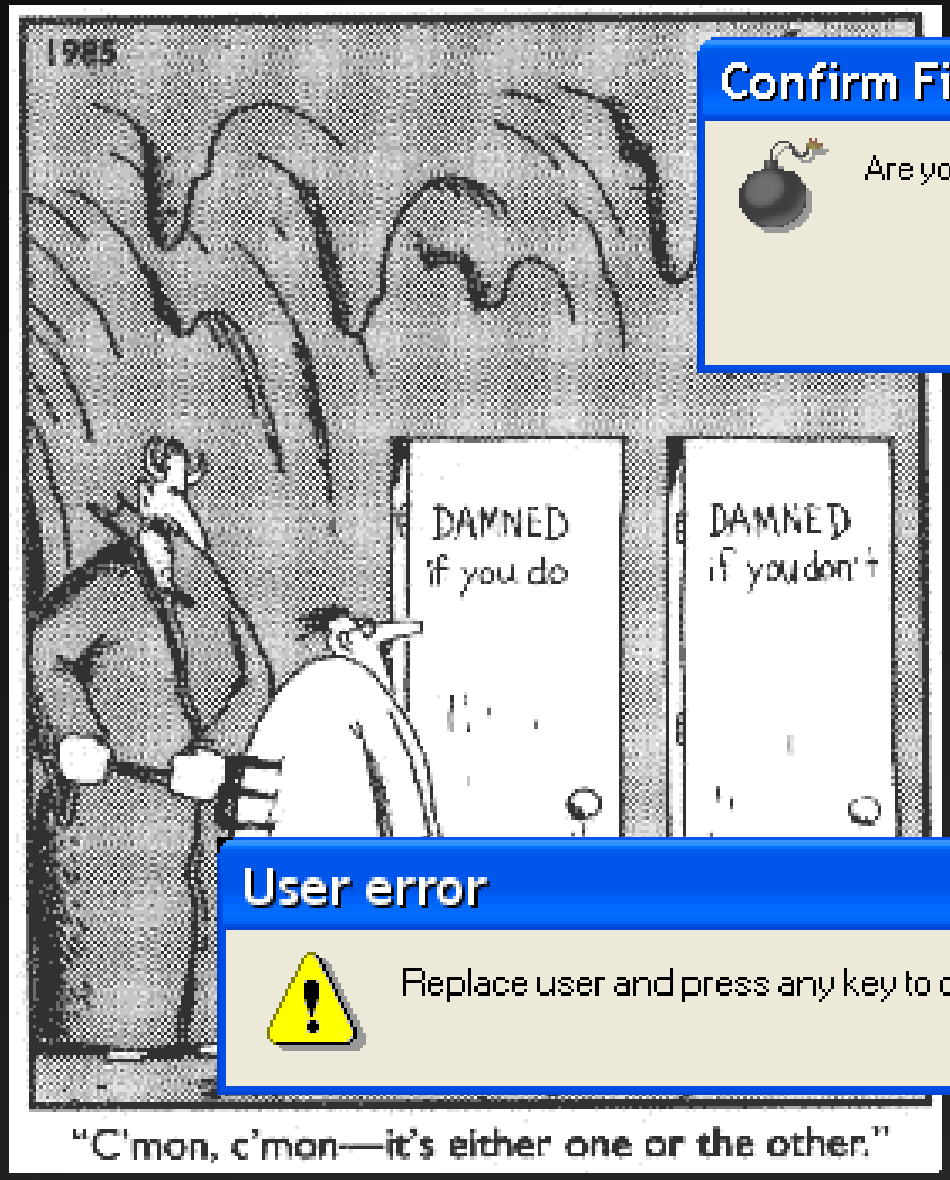


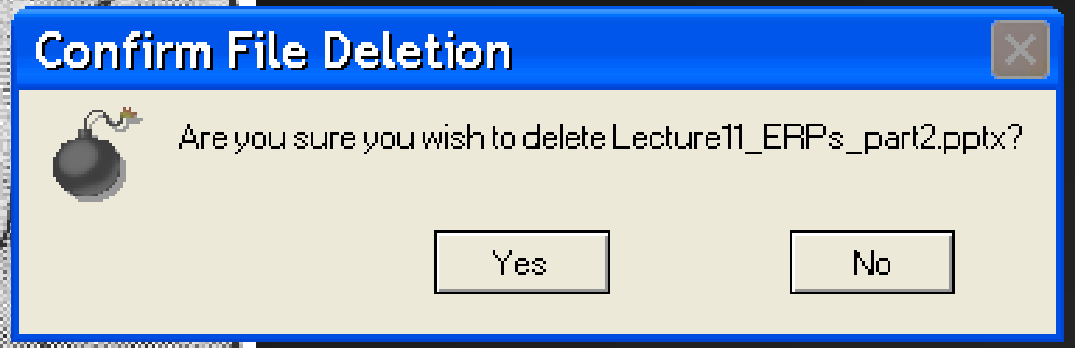
Flankers Task:

MMNMM

Also sometimes termed Ne

Life is full of choices … and consequences





The ERN

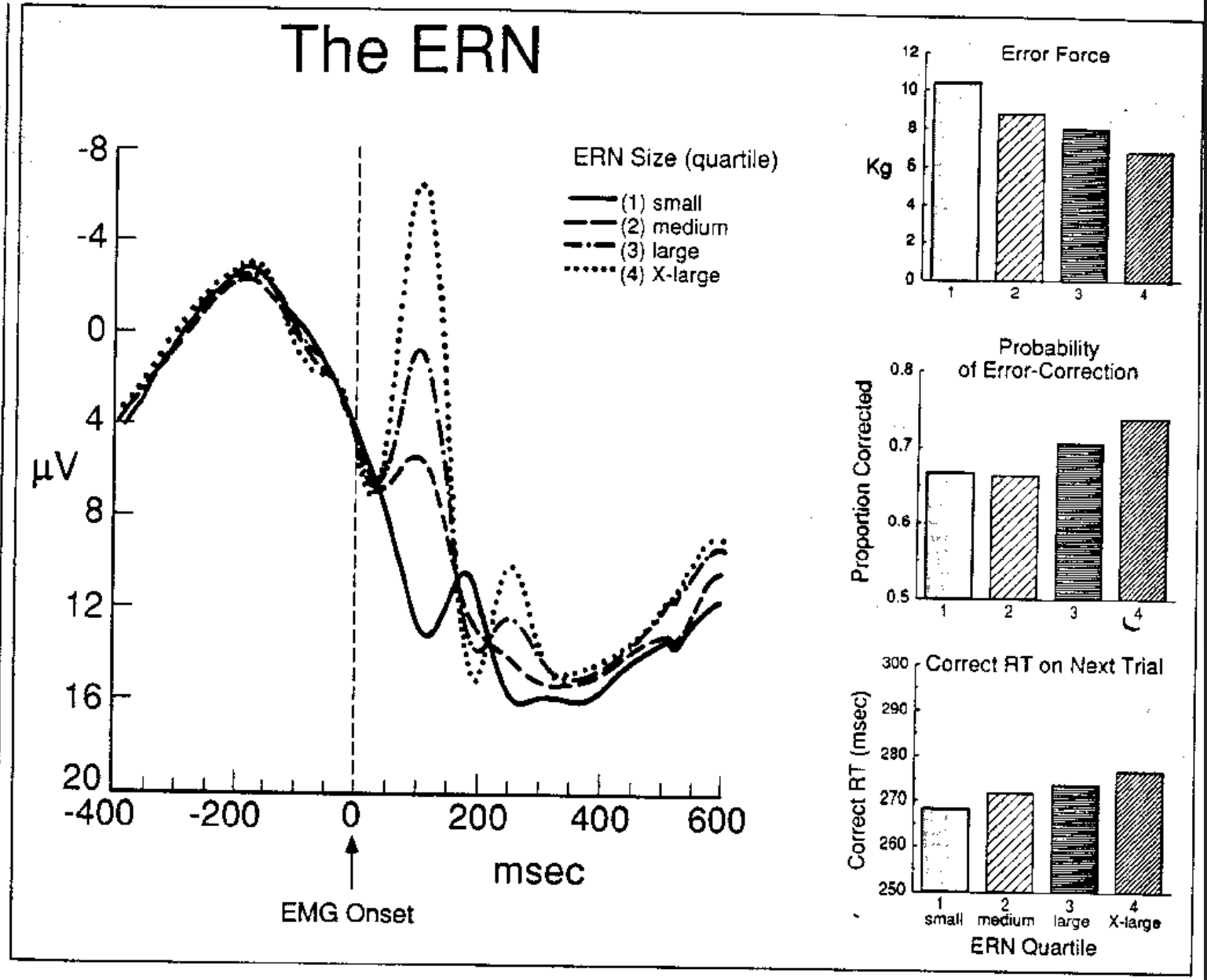


Fig. 3. Relationship between error-related negativity (ERN) amplitude and three measures of compensatory behavior. Left panel: Average event-related potentials at the C_z electrode as a function of the four levels of the posterior probability measure of ERN amplitude. Right panel, top: Error squeeze force in Kg as a function of the four ERN levels. Right panel, middle: Probability of error correction as a function of the four ERN levels. Right panel, bottom: Correct reaction time on the trial following an error as a function of the four ERN levels.

Gehring et al., 1993

Modality Specific?

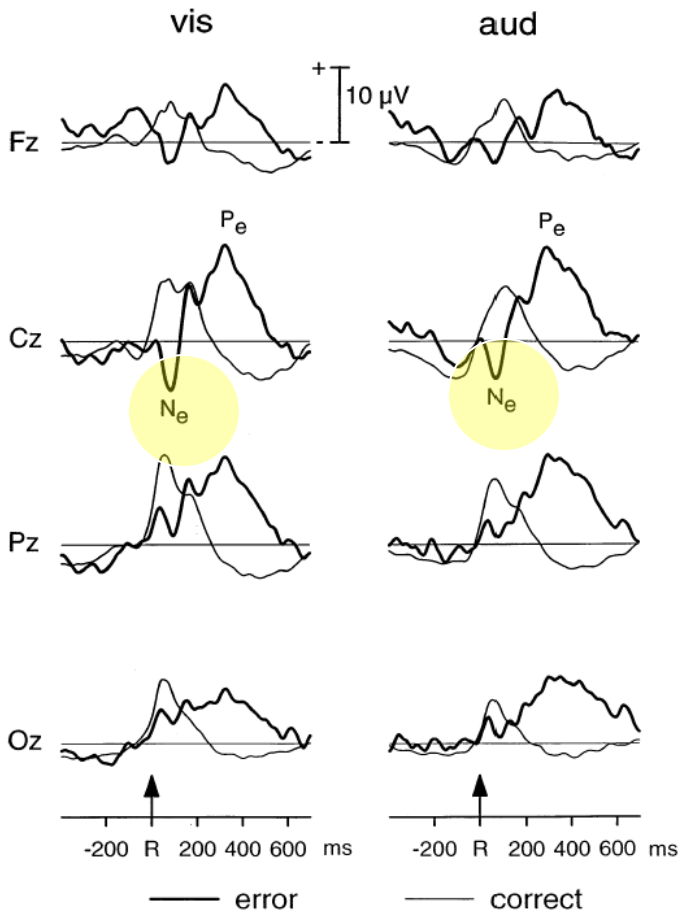
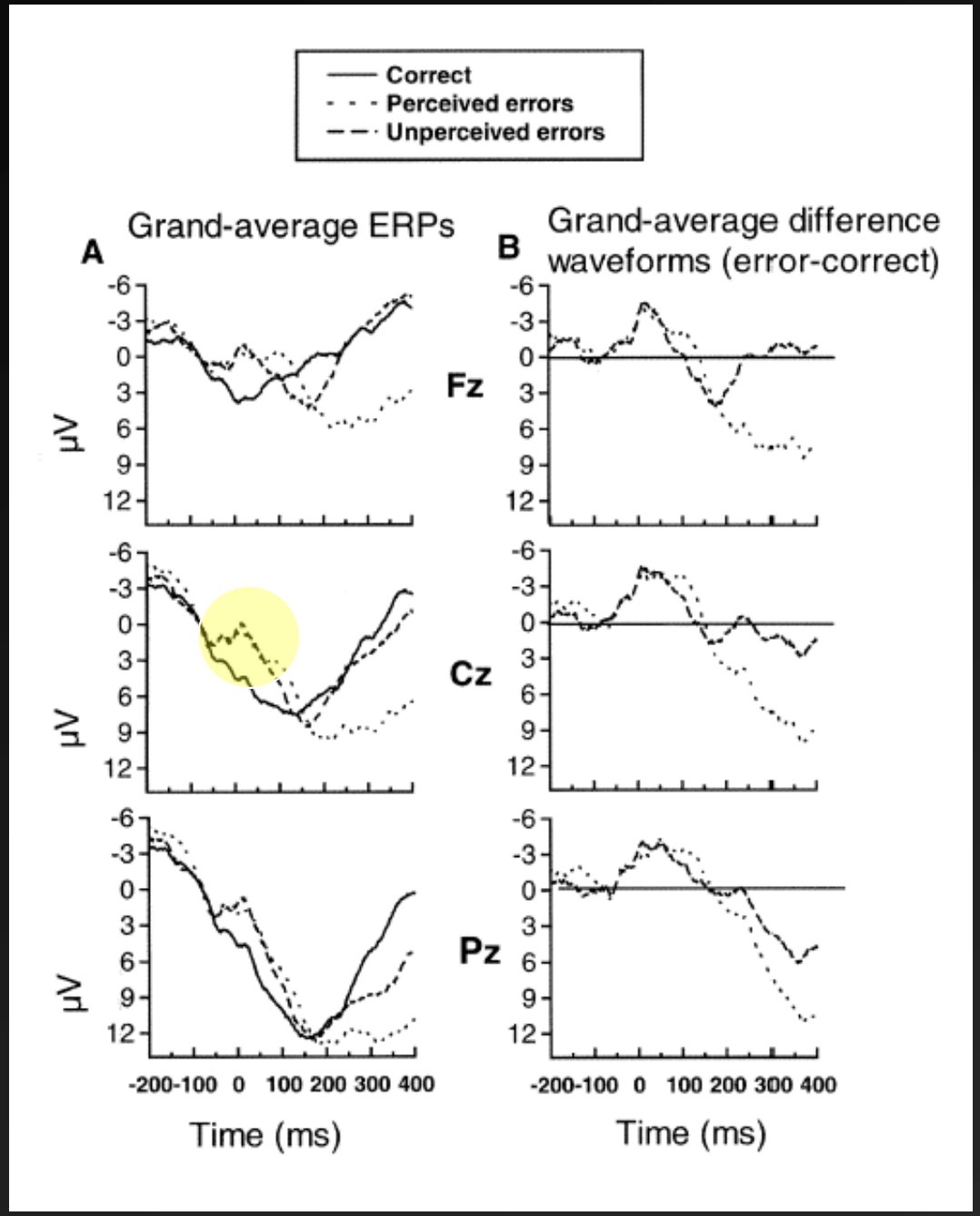


Fig. 1. Grand averages (Experiment 4; $n = 12$) of the RTA for errors (heavy lines) and correct trials (light lines) after visual (vis) and auditory letter stimuli (aud) in a 2-CR task. The error negativity ('Ne') is seen as a sharp negative deflection with central maximum peaking at about 80 ms after the incorrect key press (R). The error positivity ('Pe') is seen as a late parietal positivity with Cz maximum peaking at about 300 ms after the incorrect key press. On correct trials a positive complex with Pz maximum is seen.

- Does not matter what modality stimulus was presented



- Does not matter what modality response was made
- Eye

Nieuwenhuis et al., 2001: Anti-Saccade Task

C.B. Holroyd et al. / Neuroscience Letters 242 (1998) 65–68

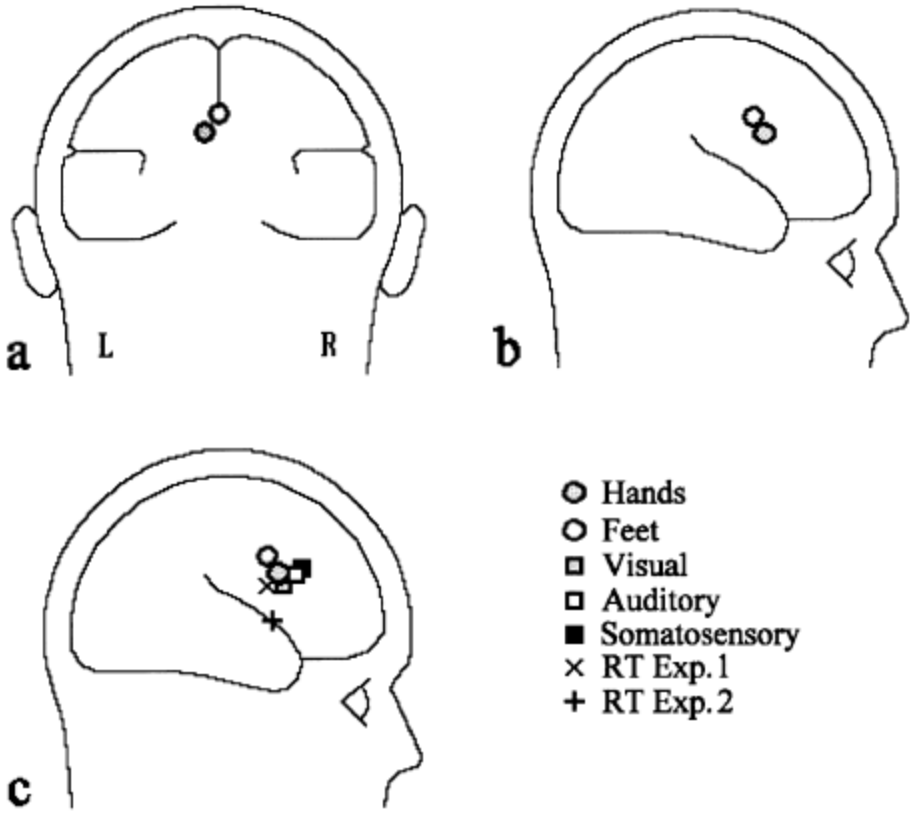


Fig. 2. Source localization of the error-related negativity. Circles represent locations of sources determined for hand and foot responses: (a) coronal view; (b) sagittal view; (c) for comparison, source locations of the ERN determined in previous studies are depicted along with the locations of the ERN obtained in the present study. Squares represent locations of sources found for ERNs elicited by visual, auditory, and somatosensory feedback [10]. Crossed symbols represent locations of sources found for ERNs elicited by errors in two reaction time experiments [2].

- Does not matter what modality response was made
  - Eye
  - Hand
  - Foot

Error Detection Vs. Error Compensation

- If Error Compensation, ERN/Ne should not be present in tasks where compensation impossible
- Ergo…
  - the Go-Nogo!
  - Play along… press only for X following X

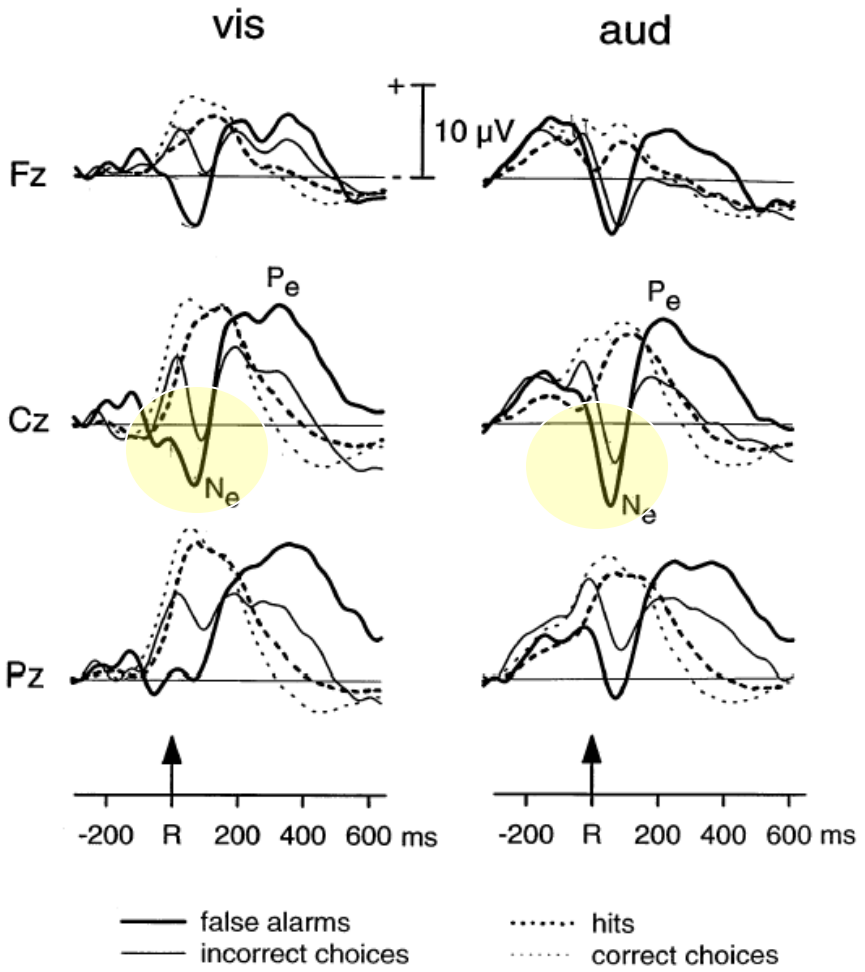


Fig. 5. Grand averages (Experiment 2; $n = 10$) of the RTA for false alarms and hits in Go/Nogo tasks (heavy lines), and choice errors and correct choice trials in two-way choice tasks (thin lines). Errors continuous lines, correct responses broken lines. The Ne is delayed relative to the incorrect key press, and the Pe is smaller, for choice errors compared to false alarms. In correct trials a positive complex with Pz maximum is seen, which is larger after visual than after auditory stimuli. However, this complex is not larger for hits than for correct choice trials.

Falkenstein Hoormann Christ & Hohnsbein, *Biological Psychology,* 2000, Summary of Falkenstein et al 1996

Error Detection Vs. Outcome Impact

- Might the “cost” or “importance” or “salience” of an error be relevant to this process?
- Studies relevant to error salience
  - Speed-accuracy trade off
  - Individual differences

Speed Vs. Accuracy

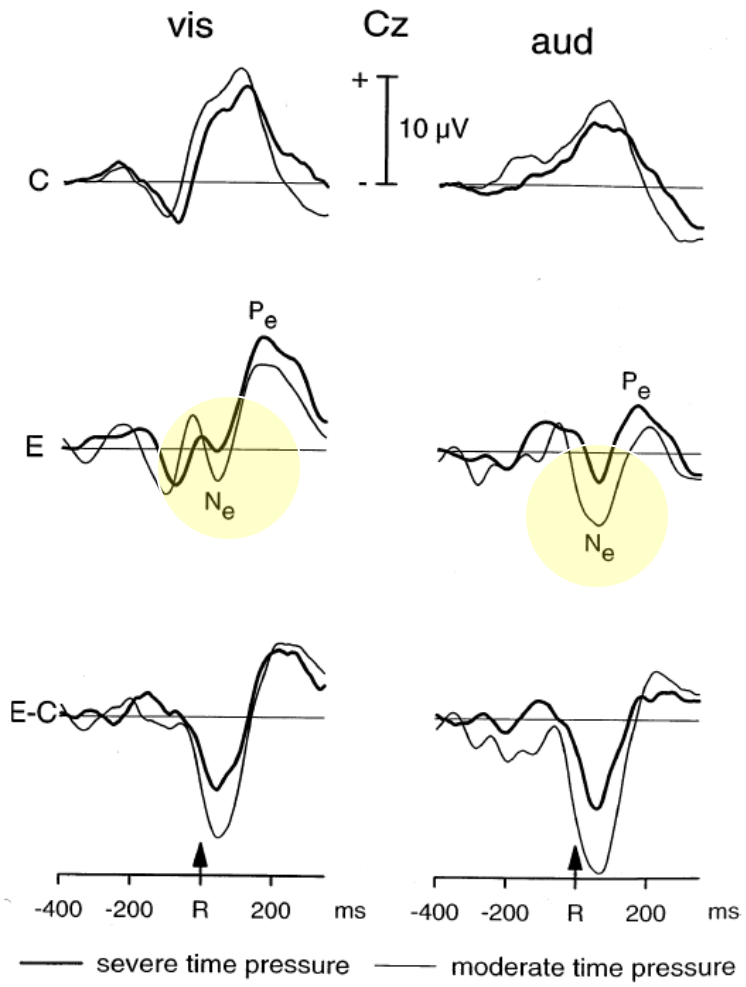


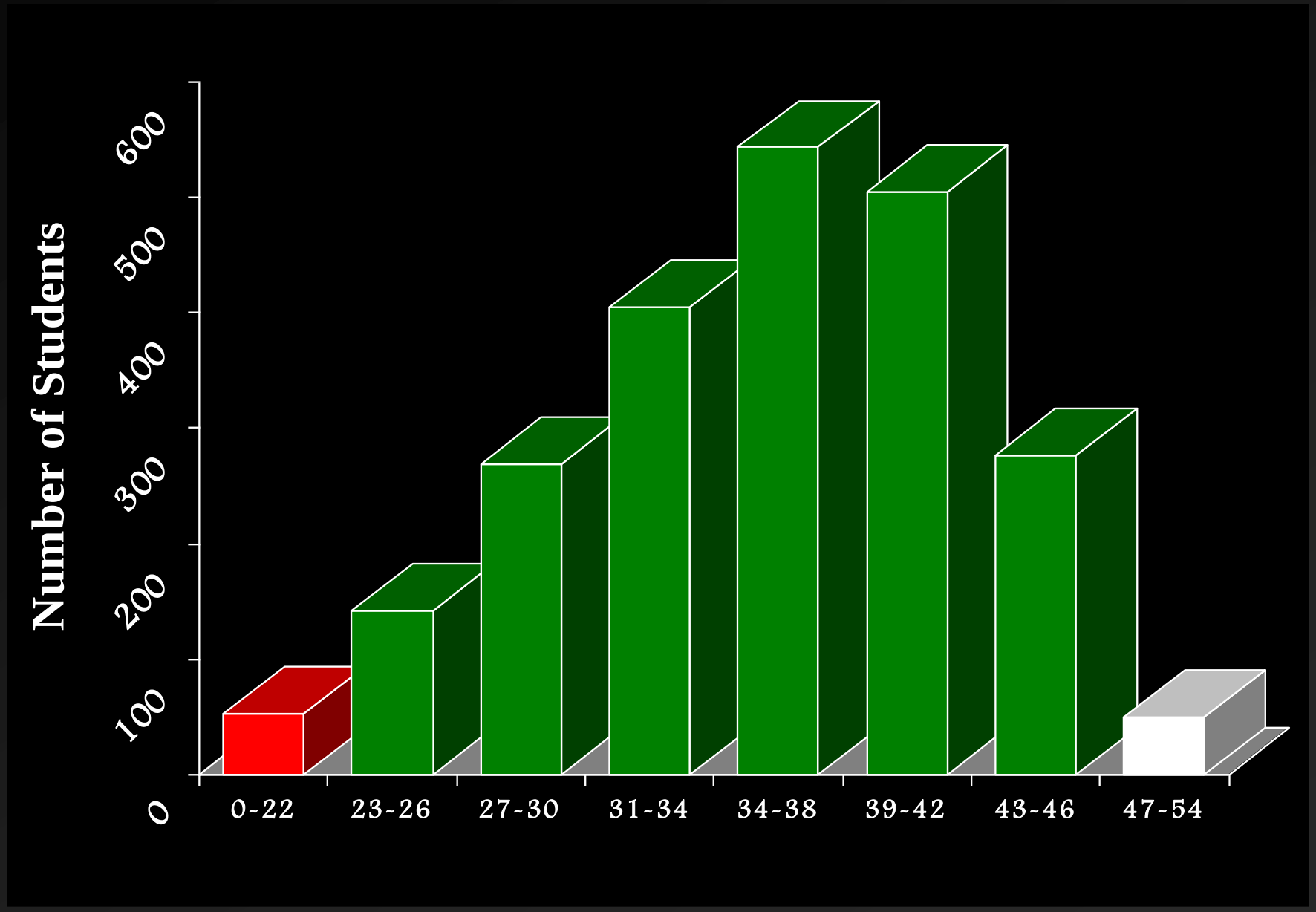
Fig. 4. Grand averages (Experiment 1; $n = 9$) of the RTA for correct responses (C), errors (E), and difference waveshapes (error minus correct; E − C) in a 2-CR task under moderate (light lines) and severe time pressure (heavy lines). The error rates were 15% (moderate) and 30% (severe); the number of error trials used was equalised for the two conditions. The Ne is smaller for severe time pressure/high error rate.

Individual Differences

- Psychopathy (or analog)
- OCD

Deficits in Error Monitoring in Psychopathy

- Psychopaths appear unable to learn from the consequences of their errors
  - Avoidance learning deficits
  - In the context of rewards *and* punishments
  - Deficient anticipatory anxiety

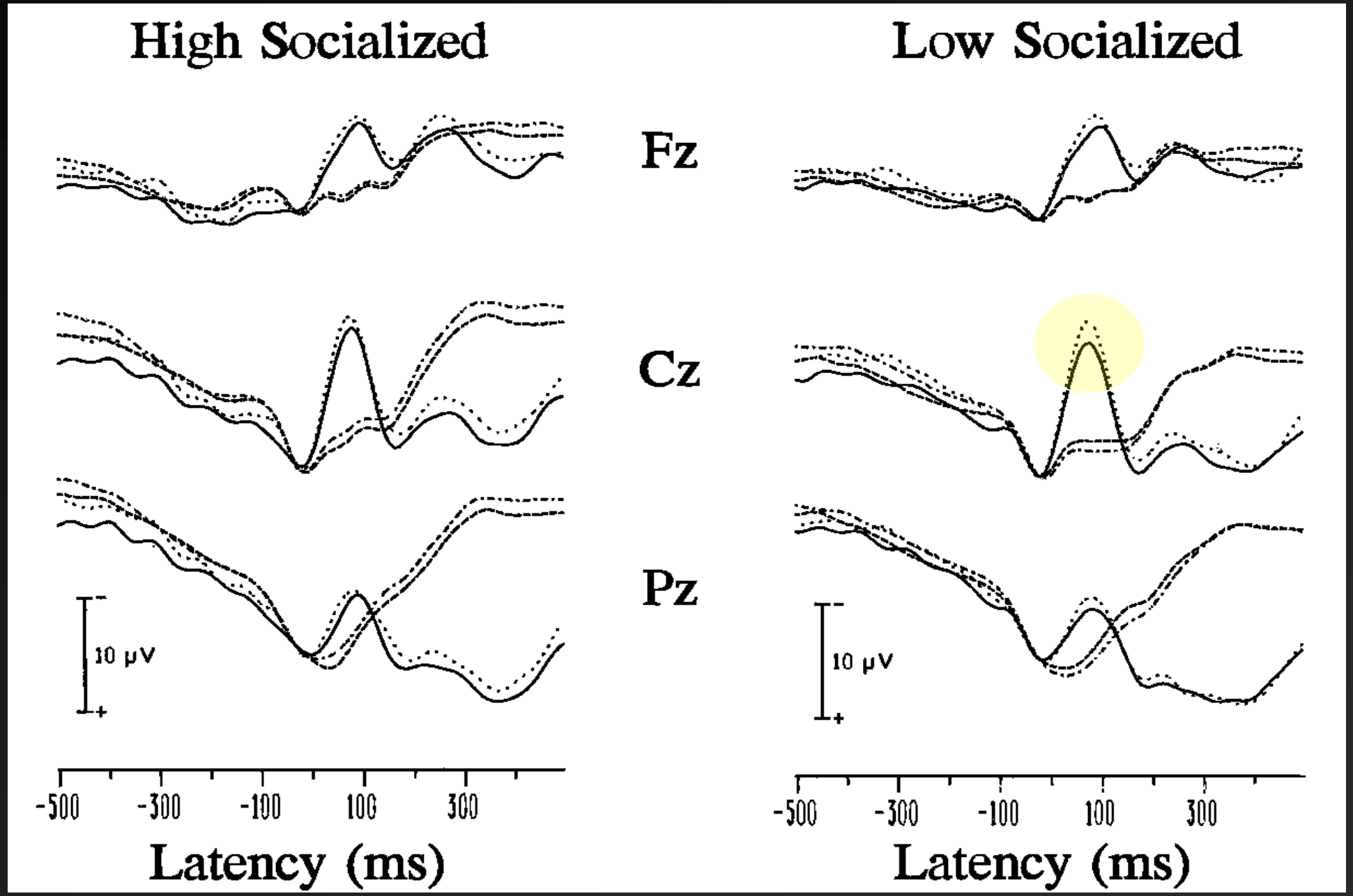


Thirty participants selected: **15 high SO**
15 low SO

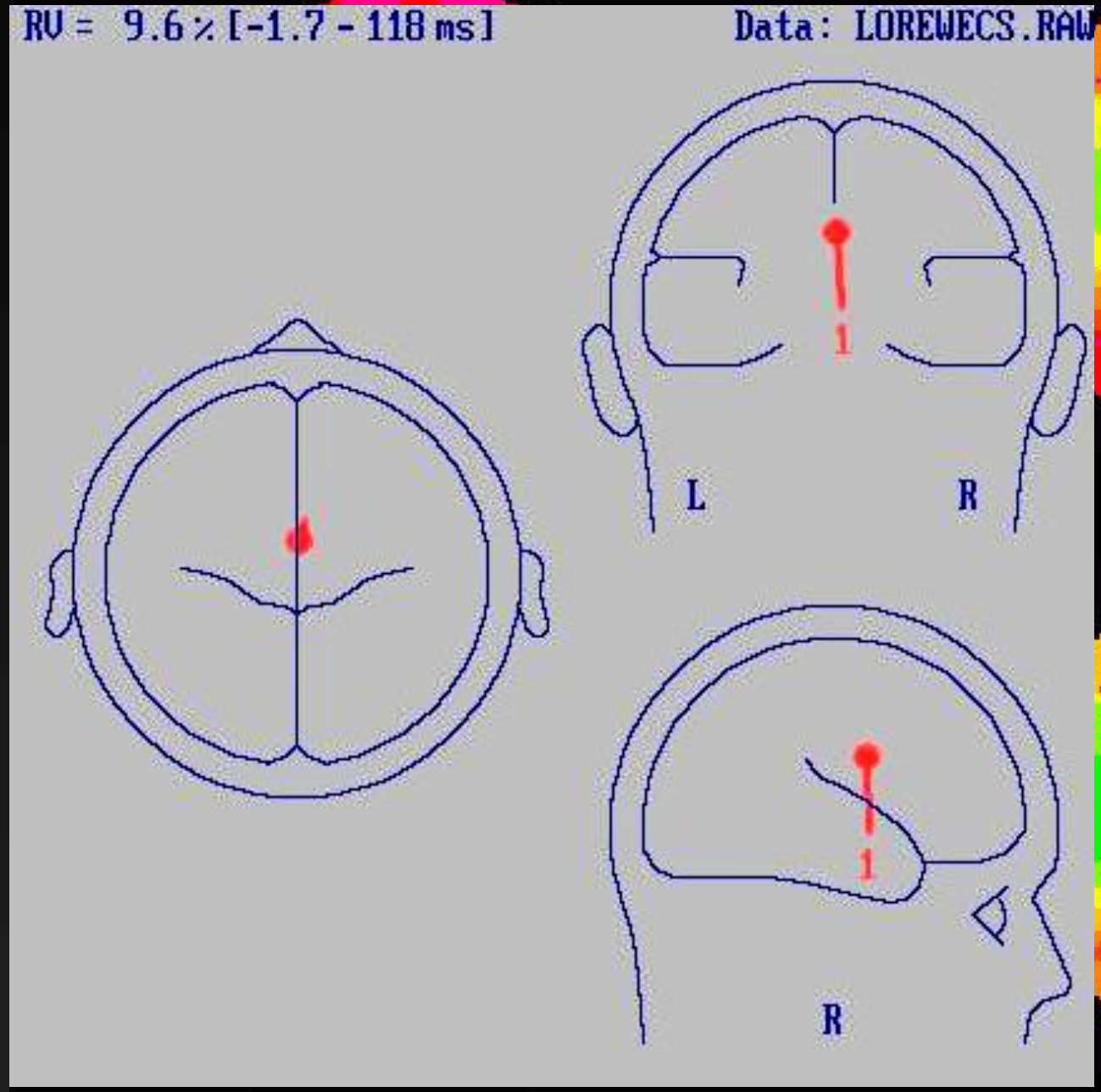
Dikman & Allen, 2000, *Psychophysiology*

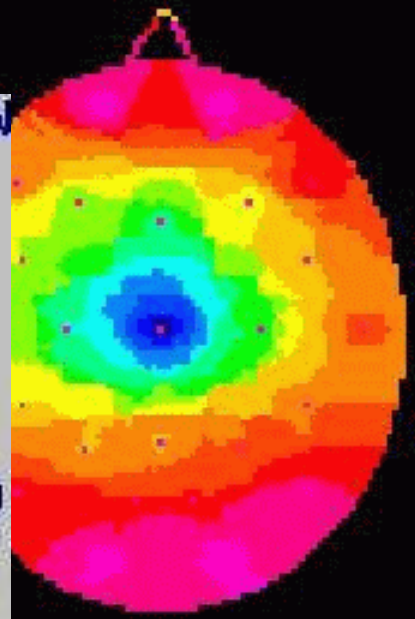
Procedure

- Eriksen flanker task: SSHSS
- Two conditions for each subject
  - Reward (REW), errors “No $”
  - Punishment (PUN), errors 95 dB tone
- Consequences of errors could be avoided by self-correcting response within 1700 msec window
- Response mapping switched at start of each of 10 blocks, total trials 600
- Only corrected error trials examined

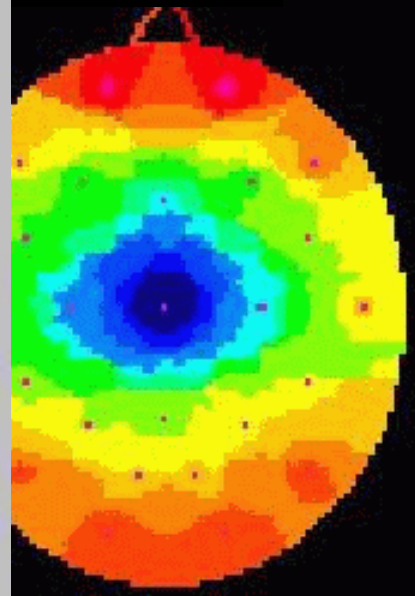


Dikman & Allen, 2000, *Psychophysiology*





Rew



Results re -matched trials

ERN in OCD

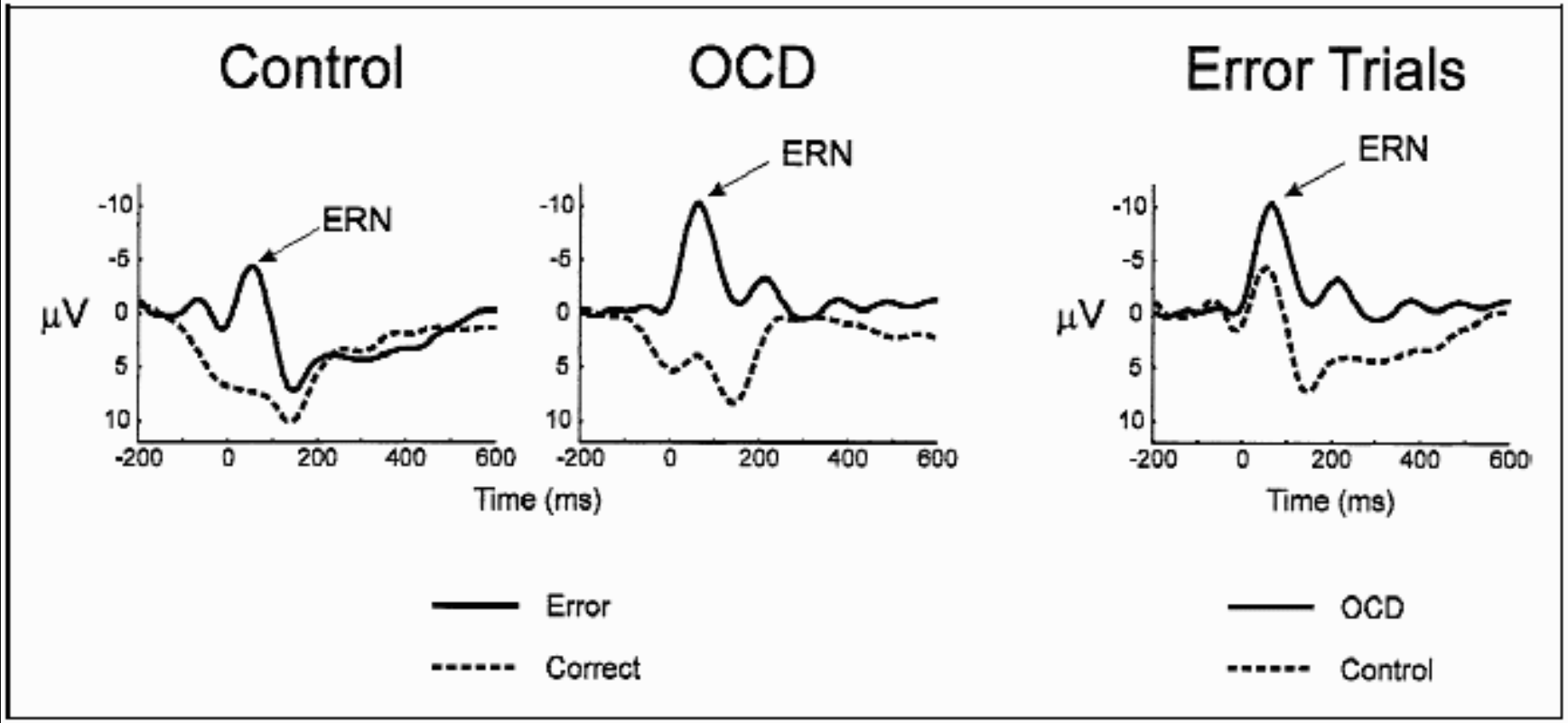


Fig. 1. Response-locked event-related potential waveforms at the Cz electrode location. The left panel compares correct-trial and error-trial waveforms for control participants and for individuals with obsessive-compulsive disorder (OCD). The right panel compares error-trial waveforms for the two groups. Times are plotted relative to the latency of the button-press response. ERN = error-related negativity.

And amplitude of ERN correlates with Symptom severity (correlation magnitude ~.50); Gehring et al. (2000)

DOI: 10.1111/psyp.13348

EARLY CAREER AWARD

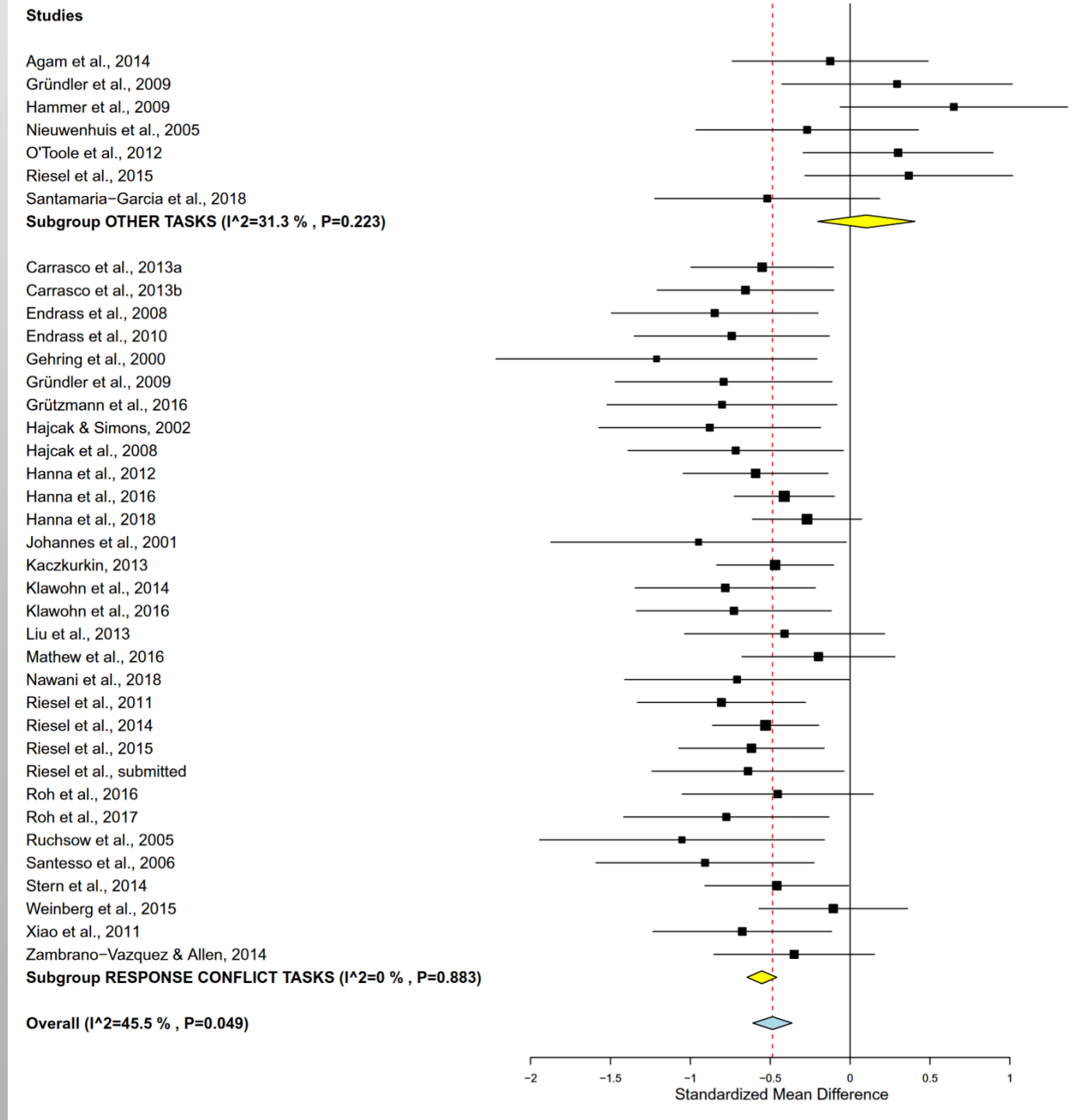
WILEY PSYCHOPHYSIOLOGY SPR

The erring brain: Error-related negativity as an endophenotype for OCD—A review and meta-analysis

Anja Riesel

Psychophysiology. 2019;56:e13348.
https://doi.org/10.1111/psyp.13348

- 1007 OCD, 1100 Control participants
- Medium effect size -.49
- Task type moderates (response conflict larger)
- Robust across:
  - Age
  - Clinical OC Severity (at study level)
  - Depression symptoms
  - Medication status
- Fail-safe N = 55

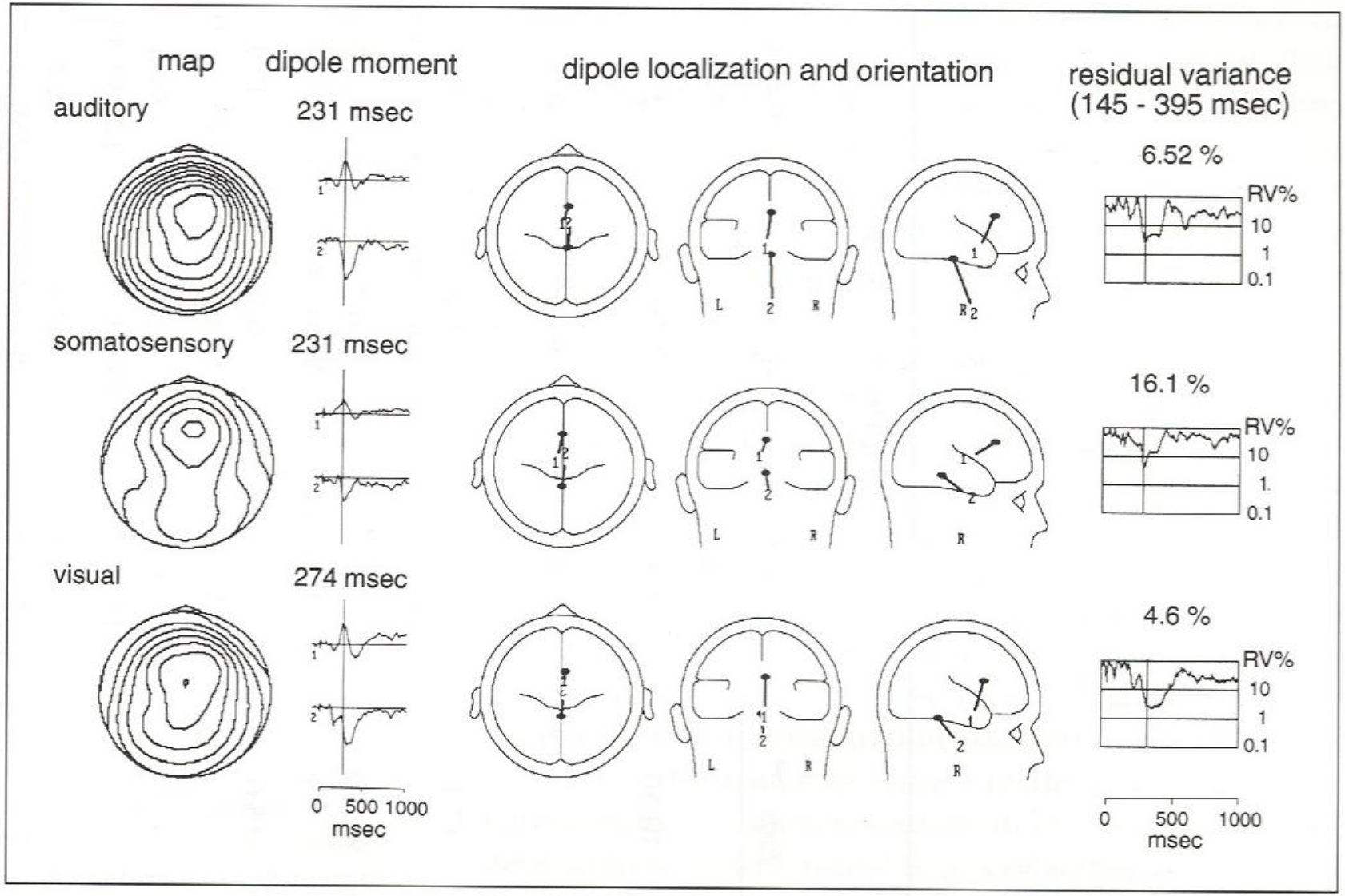


Errors and Feedback

- Endogenous Error Detection
- Exogenous Error Feedback
- Common Mechanism?

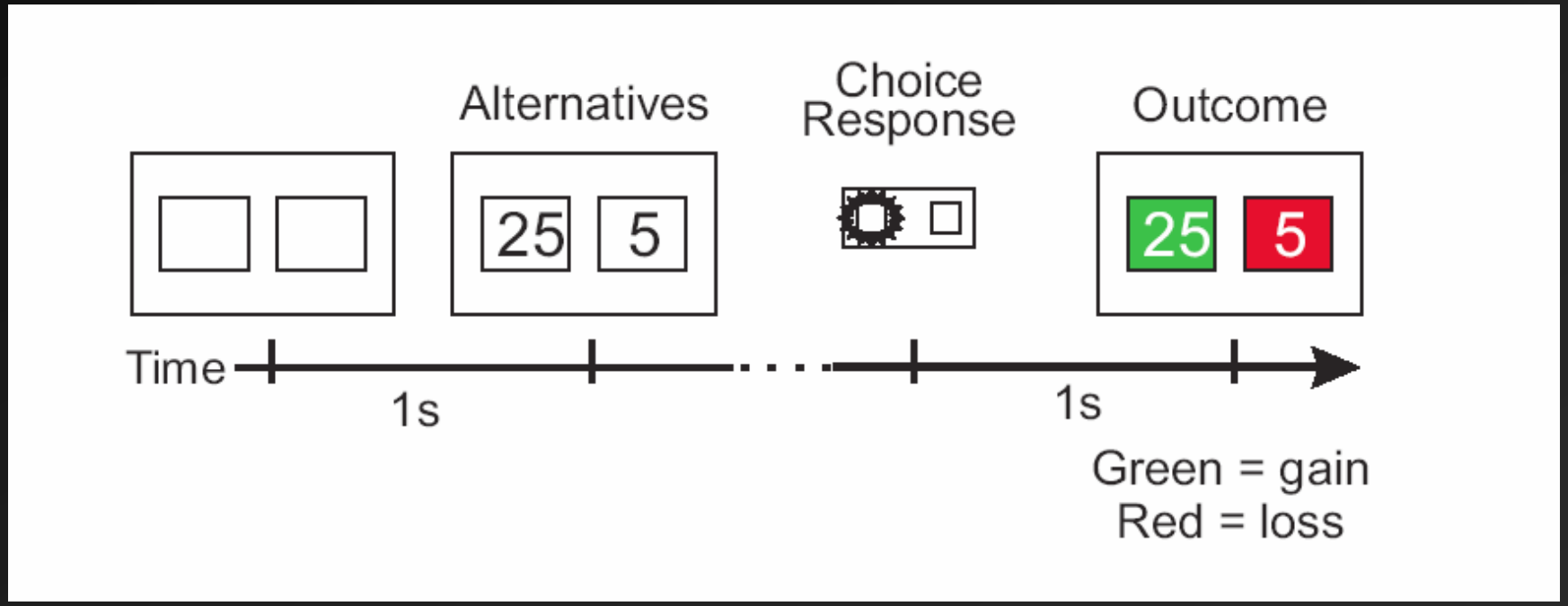
Choices and Feedback

The Feedback Medial Frontal Negativity



Miltner, Braun, & Coles, (1997) *Journal of Cognititive Neuroscience*

The Gambling Task



Gehring and Willoughby, 2002 *Science*

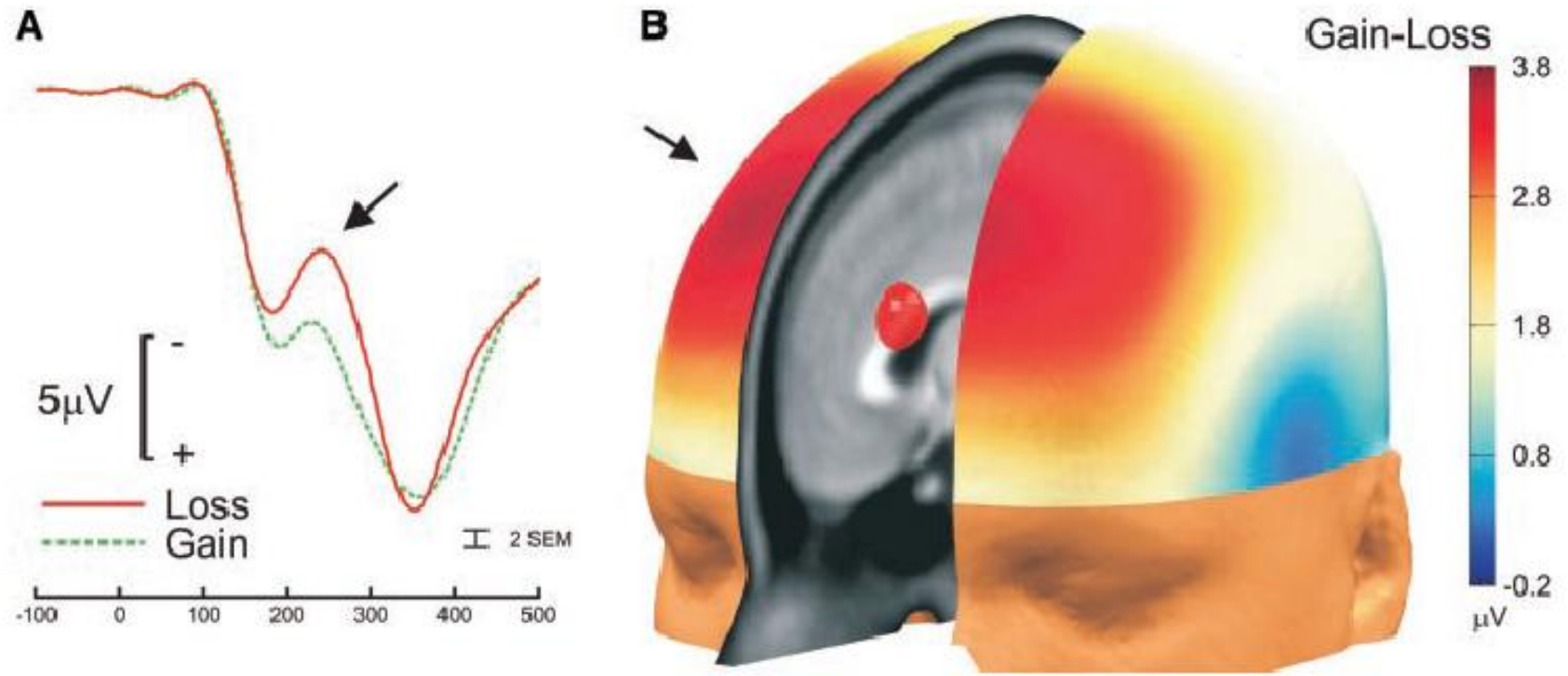
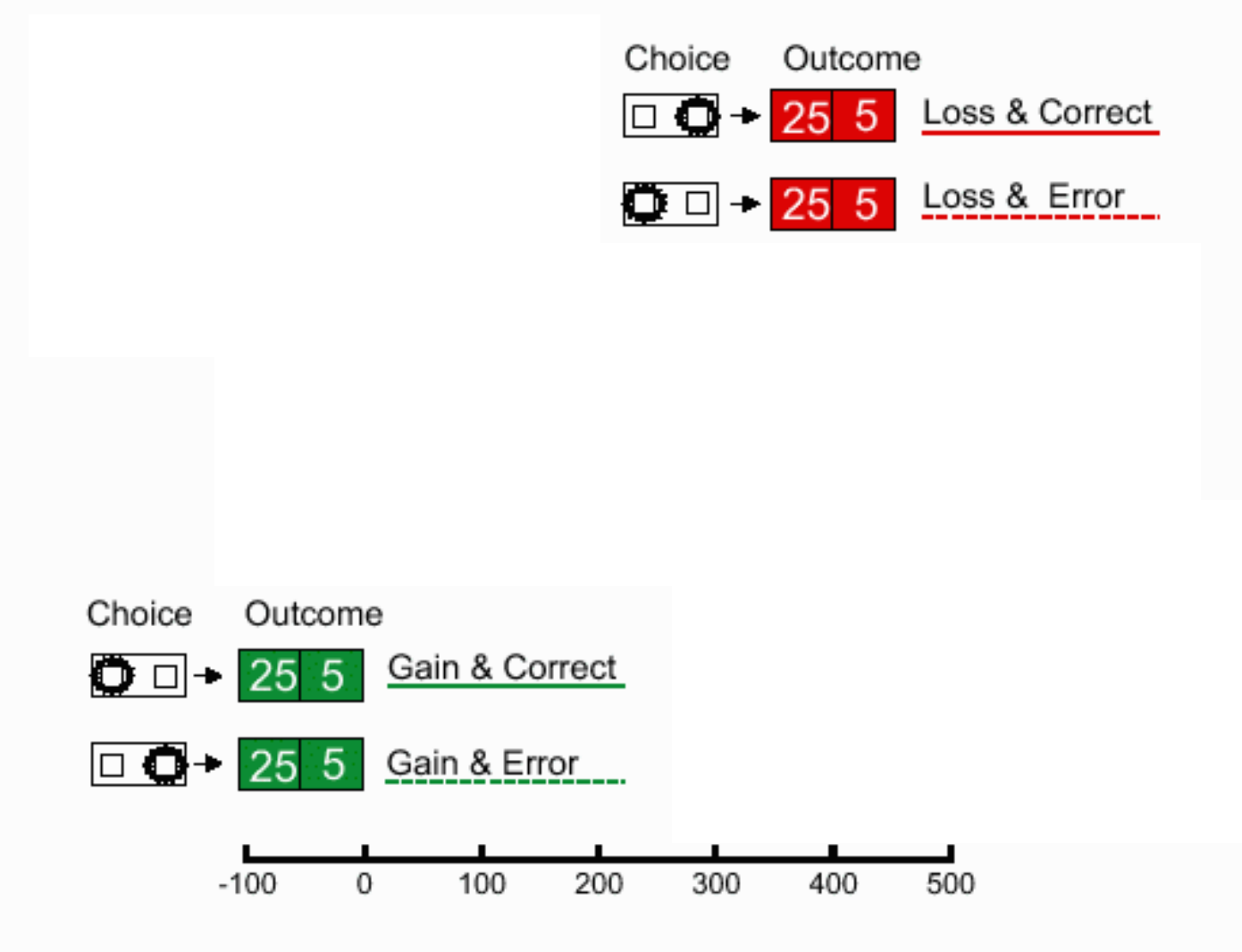


Fig. 2. ERP waveforms, scalp topography, and likely neural generator of the MFN. (**A**) The waveforms are shown at the Fz (frontal) electrode site. The solid red line corresponds to the average ERP waveform for all trials in which the participant lost money. The dashed green line corresponds to those trials in which the participant gained money. The MFN is indicated by the arrow. The error bar represents two standard errors of the mean, based on the mean squared error from the ANOVA (9). (**B**) The map of scalp activity shows the voltages, derived by subtracting the loss-trial waveform from the gain-trial waveform, computed at 265 ms after the onset of the outcome stimulus. Larger positive values correspond to a greater MFN effect. The MFN is indicated by the focus of activity at the Fz electrode (designated by the arrow). The best-fitting dipole model of the generator of the MFN is shown as a red sphere centered in the ACC on a canonical magnetic resonance imaging template of the human head (9).

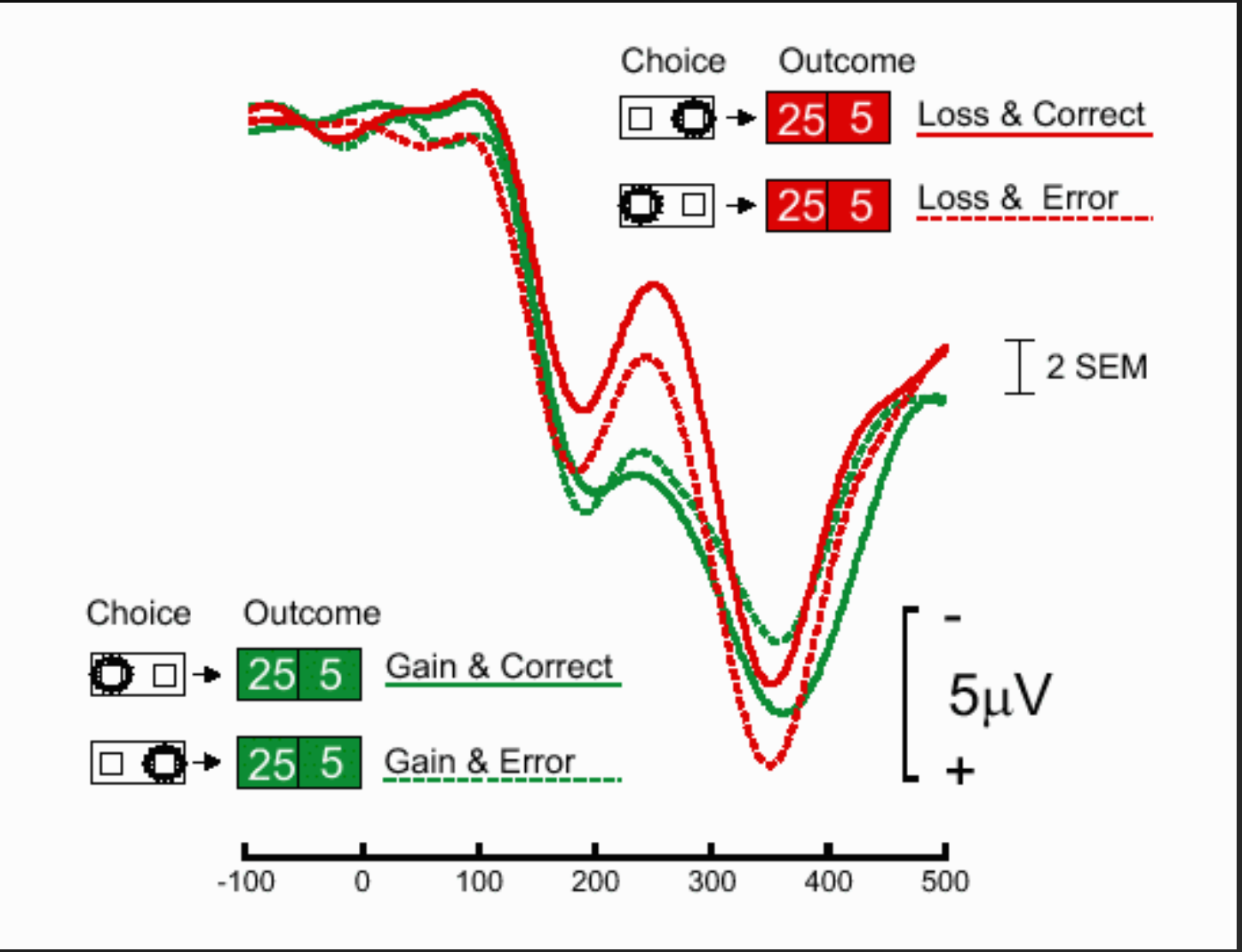
Gehring and Willoughby, 2002 *Science*

Error, or motivation?



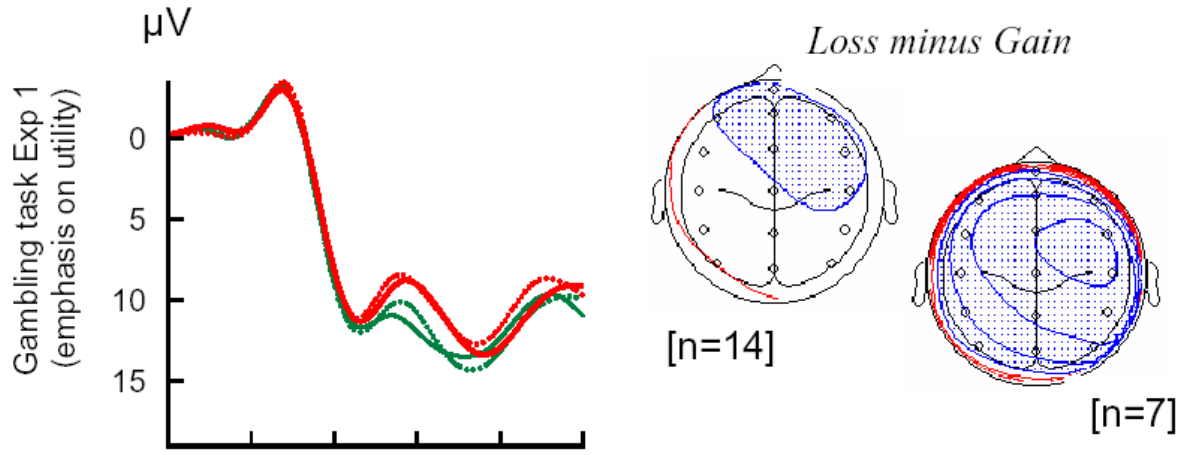
Gehring and Willoughby, 2002
Science

Error, or motivation?



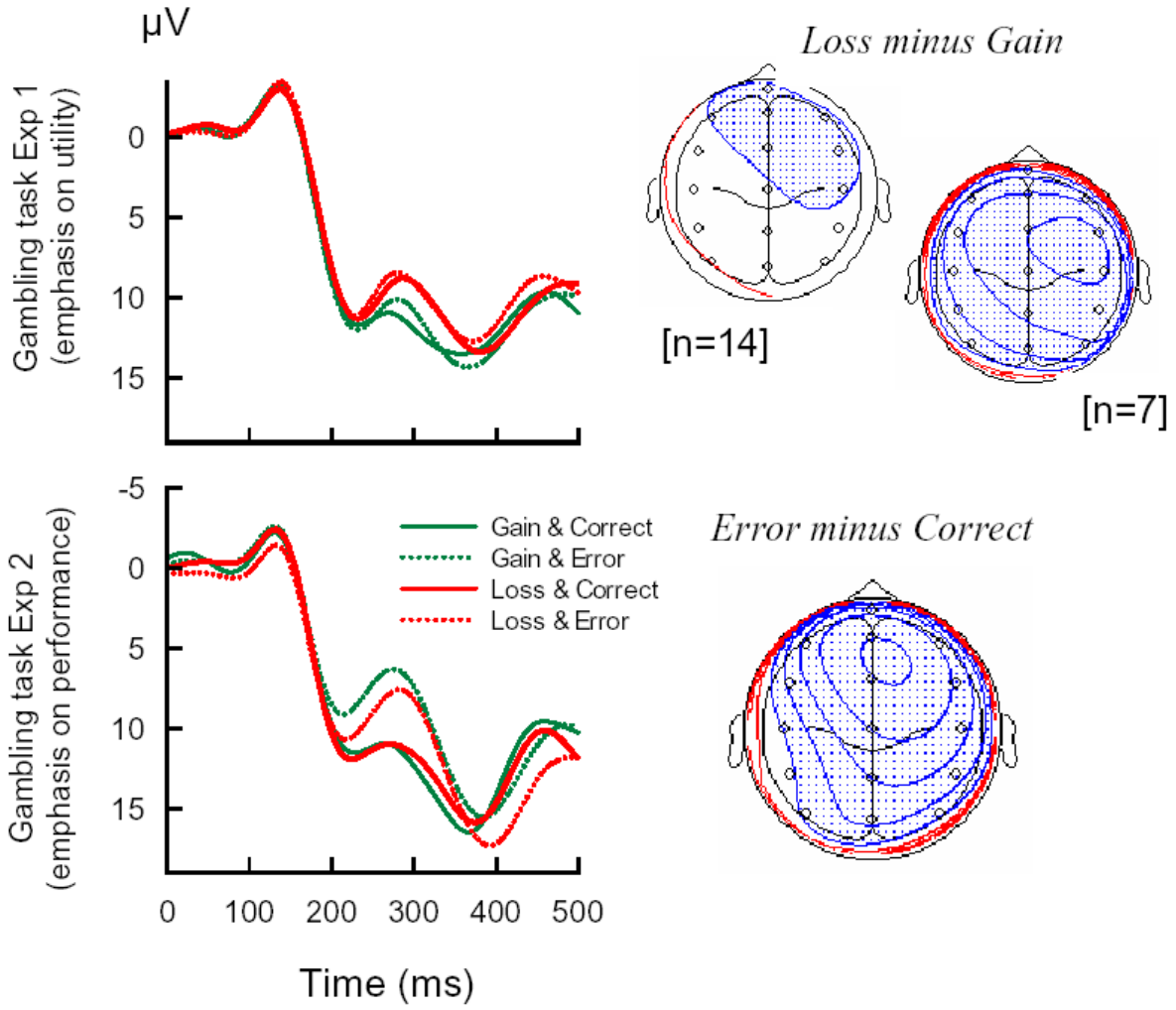
Gehring and Willoughby, 2002
Science

Effect may depend on *relevant* dimension of feedback



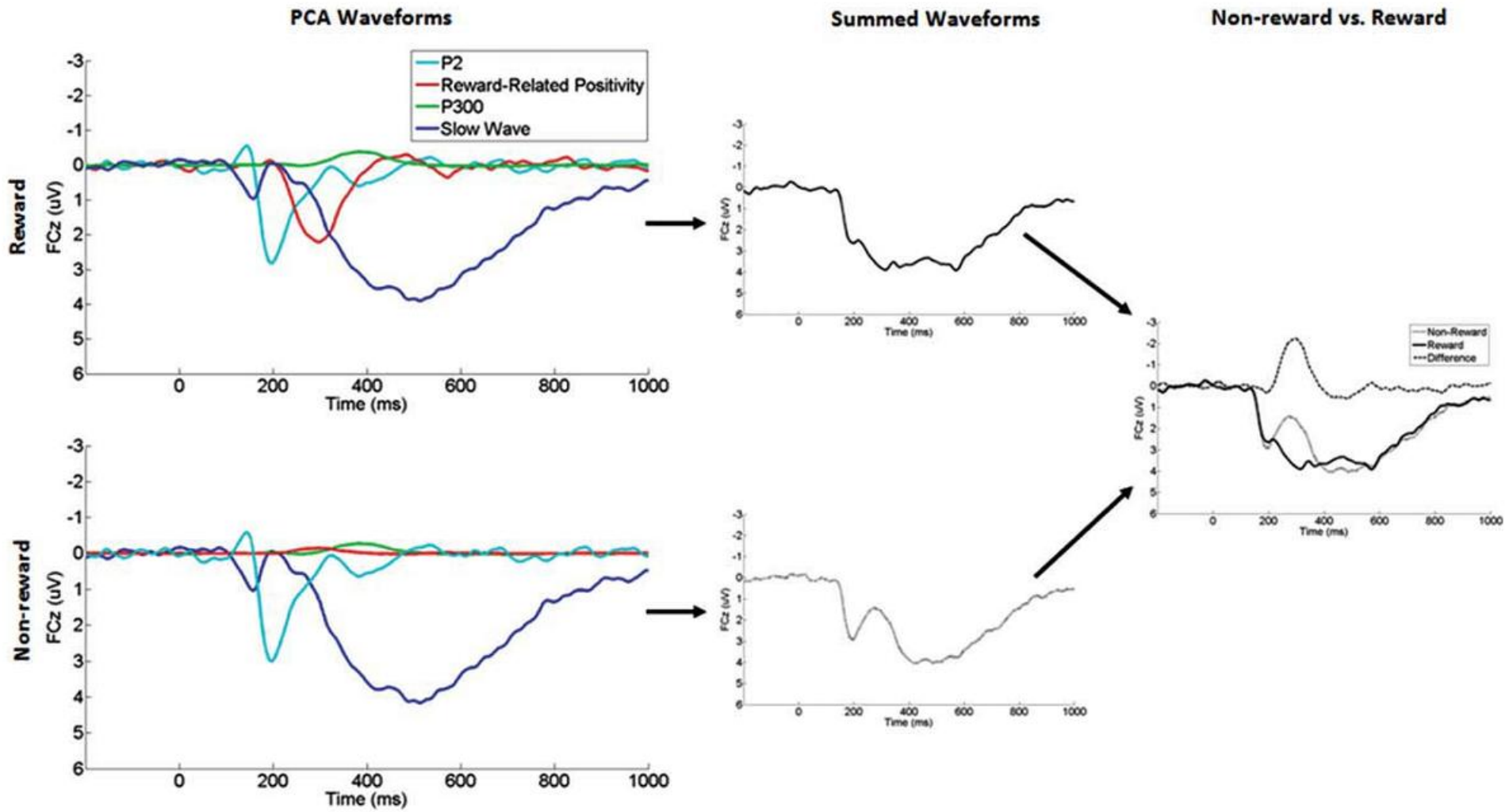
Nieuwenhuis, Yeung, Holroyd, Schurger, & Cohen (2004), Cerebral Cortex

Effect may depend on *relevant* dimension of feedback



Nieuwenhuis, Yeung, Holroyd, Schurger, & Cohen (2004), Cerebral Cortex

FRN may be absence of Reward Positivity



Foti et al. (2011). *HBM*

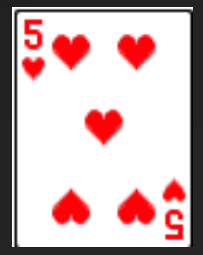
FRN and Problem Gambling

Why do Gamblers Gamble?

Black Jack Study

- 20 Problem Gamblers, 20 Controls
- Black Jack

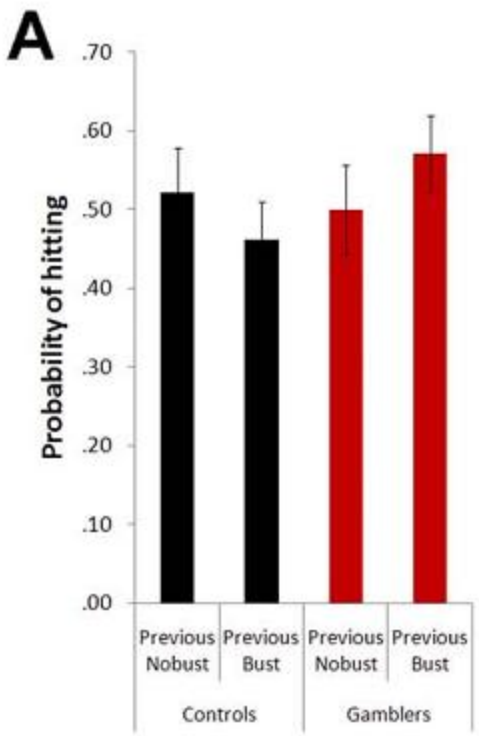
BUST!



21!

Hewig et al. (2010). *Biological Psychiatry*

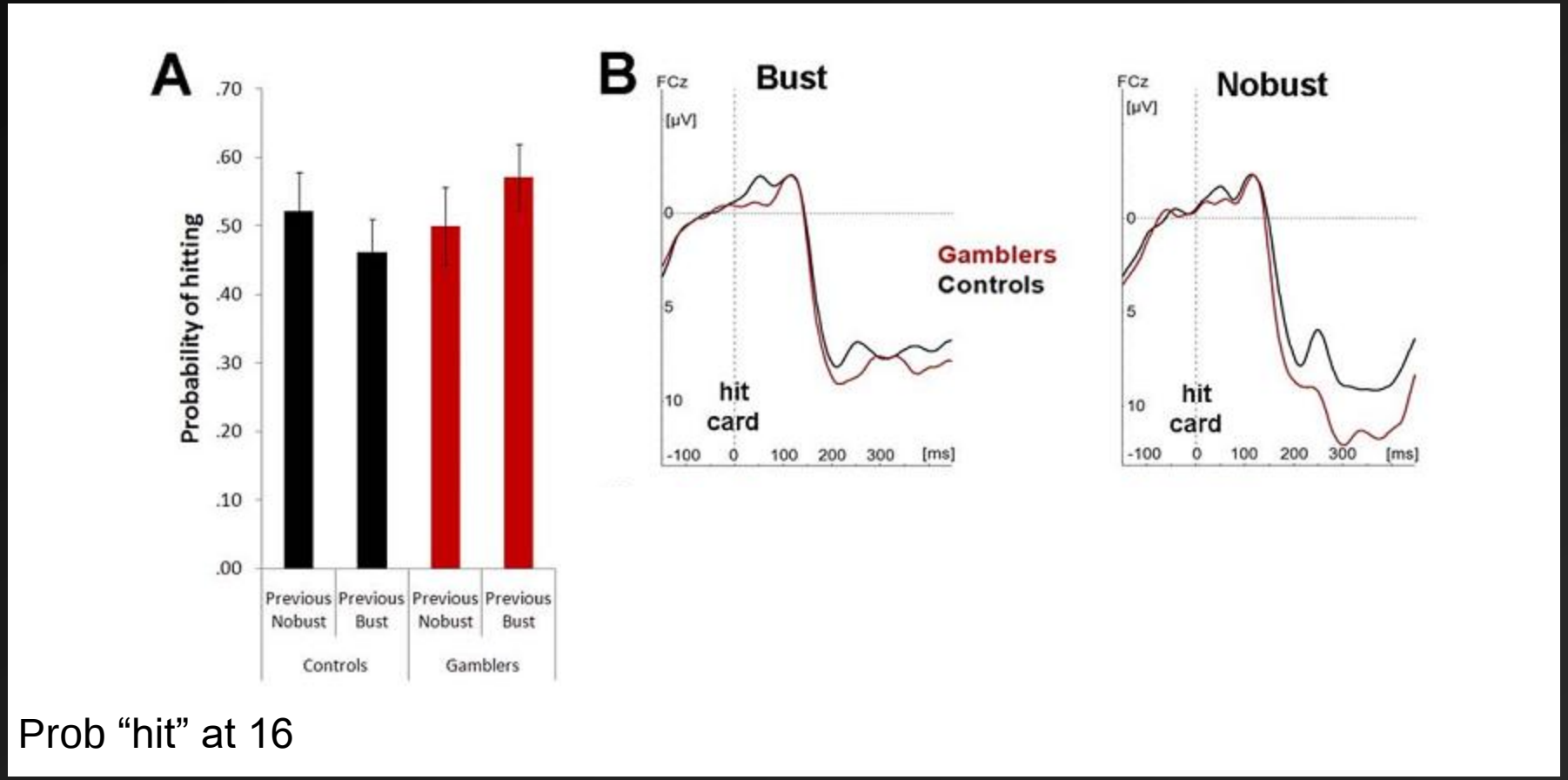
Black Jack Study



Prob “hit” at 16

Hewig et al. (2010). *Biological Psychiatry*

Black Jack Study



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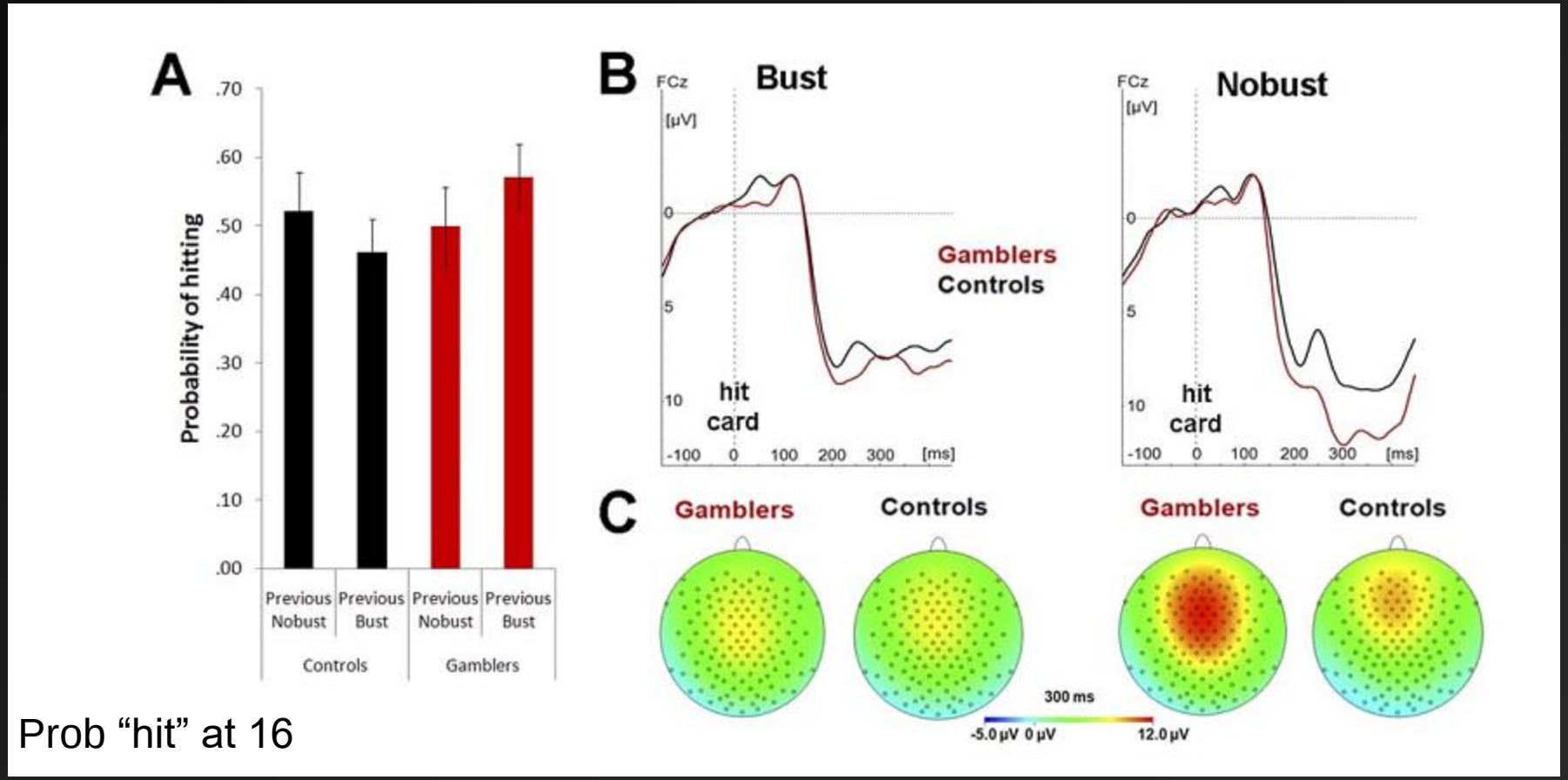
Black Jack Study



Prob “hit” at 16

Hewig et al. (2010). *Biological Psychiatry*

Conclusions

- At a critical point score of 16, problem gamblers decided more often to hit despite losses due to a bust on the preceding trial, whereas control participants decided more often to sit under these conditions.
- Problem gamblers showed more reward-related positive amplitudes in the event-related brain potential than control participants after successful hit decisions at 16.
- Results suggest that high-risk-taking behavior in problem gamblers is associated with an increased reward-related neural response to infrequent successes of this behavior.