

# *Advances in Neurobehavioral Assessment of Persons with Disorders of Consciousness*

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# The State of the Science (1983)

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*“The limits of consciousness are hard to define satisfactorily and we can only infer the self-awareness of others by their appearance and their acts.”*

*From: Plum F, Posner JB (1983). The Diagnosis of Stupor and Coma. F.A. Davis, Philadelphia, PA.*

# The State of the Science (1998)

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*“If one accepts the notion that coma is a behavioral anomaly arising secondarily to brain lesions, then one must be struck by the relative paucity of scientific research dealing with the behavioral assessment and rehabilitation of the comatose patient. Just as striking is the fact that, while highly trained medical personnel are available to the patient, acute treatment teams frequently do not include personnel highly trained in applied behavioral analysis and treatment.”*

*From: Stanczak D. Methodologic considerations in the neuropsychological study of central nervous system underarousal with a specific emphasis on coma. Neuropsychol Rev 1998;8(4):191-201.*

# The State of the Science (2008)

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*“Despite advances in neuroimaging and electrophysiologic technologies, behavioral assessment methods remain the “gold standard” for assessment of patients with disorders of consciousness... In spite of the availability of a wide range of behavioral rating scales, their psychometric properties and clinical utility in individual cases varies considerably.”*

*From: Giacino J, Smart C. Recent advances in behavioral assessment of individuals with disorders of consciousness. Curr Opin Neurol 2007;20:614-619.*

# Indications for Neurobehavioral Assessment

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- ◆ Differential diagnosis (Primary)
- ◆ Lesion localization
- ◆ Correlation with neurophysiologic studies
- ◆ Prognosis/Outcome prediction
- ◆ Treatment planning
- ◆ Assessment of treatment effectiveness

## Incidence of Diagnostic Error: *How far have we come?*

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- ◆ 37% (*Childs et al, 1993*)
- ◆ 43% (*Andrews et al, 1996*)



12 YEARS!

- ◆ 41% (*Schnakers et al, submitted 2008*)

# Sources of Diagnostic Error: Examiner

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- ◆ Misattribution of reflexive, random or simple, cortically-mediated behaviors of uncertain cognitive significance as intentional or purposeful
  - ◆ Grasp reflex, roving eye movements, moaning, blink to threat
- ◆ Insufficient sampling of behavior
  - ◆ Exams too infrequent/brief
  - ◆ Range of behaviors sampled/stimuli presented too limited
  - ◆ Complexity of behavioral prompts too high
- ◆ Failure to adhere to guidelines for administration and scoring of standardized examination procedures
- ◆ Reliance on over- or underinclusive response-time windows
- ◆ Exclusion of caretaker observations

# Sources of Diagnostic Error: Patient

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- ◆ Diurnal fluctuations in arousal level
- ◆ Paralytic and sedating medications/drugs
- ◆ Subclinical seizure activity
- ◆ Occult illness
- ◆ Pain
- ◆ Fatigue
- ◆ Response habituation
- ◆ Underlying sensory or motor impairment (eg blindness, deafness, generalized hypotonus)
- ◆ Underlying cognitive impairment (aphasia, apraxia, agnosia)
- ◆ Language barrier

# Sources of Diagnostic Error: Environment

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- ◆ High ambient noise
- ◆ Insufficient or overly-intense heating/lighting
- ◆ Restricted range of movement from restraints, immobilization techniques and clothing
- ◆ Improper seating and positioning
- ◆ Loose or tight-fitting prosthetic devices

# Advantages of *Standardized Behavioral Assessment*

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- ◆ Capture broad range of behaviors
- ◆ Detect subtle but important clinical signs
- ◆ Differentiate contingent from random behaviors
- ◆ Improve interrater reliability
- ◆ Permit quantification of findings for outcome prediction

# Neurobehavioral Rating Scales

<b>Scale</b>	<b>Target Setting</b>	<b>Target Population</b>	<b>Principal Author (Year of Publication)</b>
<b>Coma Exit Chart</b>	Inpatient rehabilitation unit	Coma/VS/MCS	Freeman EA (1993)
<b>Coma Observation Scale</b>	Inpatient rehabilitation unit	Coma/VS/MCS	Gruner M (2000)
<b>Coma-Near Coma Scale (CNC)</b>	Inpatient rehabilitation unit	Coma/VS/MCS	Rappaport M (1992)
<b>Comprehensive Level of Consciousness (CLOCS)</b>	ICU	Coma	Stanczak DE (1984, 1996)
<b>Disorders of Consciousness Scale (DOCS)</b>	Inpatient rehabilitation unit	Coma/VS/MCS	Pape T (2005)
<b>Full Outline of Unresponsiveness (FOUR)</b>	ICU	Coma	Wijdicks E (2005)
<b>Glasgow Coma Scale (GCS)</b>	ICU	Coma	Teasdale G (1974)
<b>Glasgow-Liege Scale</b>	ICU	Coma	Born JD (1988)
<b>Innsbruck Coma Scale</b>	ICU	Coma	Benzer AG (1991)

# Neurobehavioral Rating Scales

<b>Scale</b>	<b>Target Setting</b>	<b>Target Population</b>	<b>Principal Author (Year of Publication)</b>
<b>JFK Coma Recovery Scale- Revised (CRS-R)</b>	ICU/Inpatient rehabilitation unit	Coma/Vs/MCS	Giacino JT (1991, 2004)
<b>Lowenstein Communication Scale</b>	Inpatient rehabilitation unit	ICU/Acute Care	Borer-Alafi NM (2002)
<b>Neuropsychological Assessment Technique</b>		Paralyzed/Nonverbal Pt	Neumann N (2004)
<b>Reaction Level Scale (RLS-85)</b>	ICU	Coma	Stallhammar DJ (1986)
<b>Sensory Modality Assessment Technique (SMART)</b>	Inpatient rehabilitation unit	Vs/MCS	Gill-Thwaites H (1997, 2004)
<b>Sensory Stimulation Assessment Measure (SSAM)</b>	Inpatient rehabilitation unit	Vs/MCS	Rader MA (1989)
<b>Wessex Head Injury Matrix (WHIM)</b>	ICU/Inpatient rehabilitation unit	Coma/Vs/MCS	Shiel A (2000)
<b>Western Neuro Sensory Stimulation Profile (WNSSP)</b>	Inpatient rehabilitation unit	Vs/MCS	Ansell BJ (1989)

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# *Characteristics of Some Recent and Widely-Used Neurobehavioral Rating Scales*

# Coma Near Coma Scale

**RAPPAFORT COMA/NEAR-COMA SCALE**  
(For patients with a Disability Rating Scale score  $\geq 21$ , i.e., Vegetative State)  
(Complete form twice a day for 3 days then weekly for 3 weeks; every two weeks thereafter if DR score  $\geq 21$ . If DR  $< 21$  follow weekly with DR scores.)

NAME: \_\_\_\_\_ SEX: \_\_\_\_\_ BIRTHDATE: \_\_\_\_\_ TYPE OF INJURY: NEVA \_\_\_\_\_ STRIKE \_\_\_\_\_ DR \_\_\_\_\_  
DATE OF INJURY/ILLNESS: \_\_\_\_\_ DATE OF ADMISSION: \_\_\_\_\_ HEALTH INSURANCE: \_\_\_\_\_ AMXUSA \_\_\_\_\_ DATE: \_\_\_\_\_

FACILITY: \_\_\_\_\_ WARD: \_\_\_\_\_ URBAN (circle) \_\_\_\_\_ TOWN \_\_\_\_\_

Parameter	Item No.	Stimulus	No. of Trials	Response Measure	Score if Positive	Score if Negative
AUSCULTORY*	1	Bell ringing 2 sec. at 10 sec. intervals	3*	Eye opening, or orientation toward sound	0 2 4	3X 1 or 2X No response
	2	Request patient to open or close eyes, mouth, or move finger, hand or leg	3	Response to command	0 2 4	Response to command 2 or 3X Response to command 3X No response
VISUAL with stimulus**	3	Light flashes (1 sec. 1/4 in front, slightly left, right, and up and down each) 1 sec.	2	Headset or aversive	0 2 4	Spontaneous headset or aversive $\geq 3X$ Spontaneous headset 3X None
	4	Talk person "look at me", move face 10" away, forehead to side	2	Response to looking	0 2 4	Spontaneous looking or head 3X Partial looking 1 or 2X No looking
THERMAL	5	50-60° water held toward or within 1-2" of nose	2	Eye blink	0 2 4	3 blinks 1 or 2 blinks No blinks
	6	Alcohol (40% v/v) introduced 1-2" from forehead	2	Withdrawal (eye or other response) toward stimulus	0 2 4	Response 2 or 3X (eye or 1) Spontaneous withdrawal 3X No withdrawal or response
TACTILE	7	Stimulate hair "the shoulder really tickle" without speaking to patient, each side	1*	Head or eye orientation or shoulder shrug toward hair	0 2 4	Orientation toward hair 2 or 3X Partial orientation 3X No orientation or response
	8	Hold each hand, medial, ulnar, and radial side of each palm 4-6" from eye	1*	Withdrawal or eye blink or mouth stretch	0 2 4	Clear, quick (eye 2 or 3 or 3X) Partial or mouth stretch 3X No response
HEAR (After up to 10 sec. for response; if small loud ringer check tone _____ 6" or greater 10")	9	Thin stick edge 10" parallel to head of each ear 10 sec. each side	3*	Eye Saccade	0 2 4	Withdrawal 2 or 3X Eye saccade toward ear 3X No response
	10	Brush ear glabella (10"), each side	3*	Withdrawal or other response toward stimulus	0 2 4	Response 2 or 3X Eye saccade toward ear 3X No response
HEAR ALLEGATIONS*** (Warning to technicians: Do not speak to patient unless he/she has eyes)	11	None (Other test subject)	—	See Score System	0 2 4	Spontaneous headset Max 10 sec. (to allow for time, grow) 3X No words

COMMENTS: (Include response changes in special conditions such as response, presence, heterogeneity, etc.) (Other issues, etc.)

Total CMC Score (add above) \_\_\_\_\_ A  
Number of items scored \_\_\_\_\_ B  
Average CMC Score (A  $\div$  B) \_\_\_\_\_ C  
Coma/Near Coma Level (see key) \_\_\_\_\_ D

\*Rappaport et al., Disability Rating Scale for Severe Head Trauma Patients: Coma to Community. Arch Phys Med Rehabil, 63:118-123, 1982 (Revised Form 1987)  
\*\*See book for TRAINING NOTES and COMA/NEAR-COMA LEVELS.  
\*\*\*If possible use them when auditory evoked response (BAER) test is not available to help establish ability to hear in at least one ear.  
\*\*\*\*Winkler or not patient appears responsive to speech, speak encouragingly and expectantly for about 10 sec. to help establish awareness that another person is present and advise patient you will be asking him/her to make a simple response. Then request the patient to try to make the same response with brief priming before 3rd, 5th and subsequent trials.  
\*\*\*\*\*Make sure patient is not sleeping. Check with nursing staff on eye-opening ability and arousability.  
\*\*\*\*\*Each side up to 3X if needed.  
\*\*\*\*\*Consult with nursing staff on arousability; do not judge solely on performance during testing. If patient is sleeping, repeat the assessment later.  
Revised 8/90

Construct Validity	IRR	TRR	IC	Sens PPV	Spec NPV
Yes	Yes	No	Yes	No	No
DRS/EPs					

Rappaport M, Dougherty AM, Kelting DL (1992). Evaluation of coma and vegetative states. Arch Phys Med Rehabil 73: 628-634.

# CNC Applications

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- ◆ Characterization of motor profiles associated with VS and MCS (*Pilon, et al., 1996*)
- ◆ Measurement of effectiveness of structured sensory stimulation (*Talbot, et al., 1994*)
- ◆ Identification of patients with favorable recovery potential (*Rappaport, et al., 1992*)

# JFK Coma Recovery Scale- Revised

JFK COMA RECOVERY SCALE - REVISED ©2004																
Record Form																
This form should only be used in association with the "CRS-R ADMINISTRATION AND SCORING GUIDELINES" which provide instructions for standardized administration of the scale.																
Patient:		Diagnosis:					Etiology:									
Date of Onset:		Date of Admission:														
Date																
Week	ADM	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<b>AUDITORY FUNCTION SCALE</b>																
4 - Consistent Movement to Command *																
3 - Reproducible Movement to Command *																
2 - Localization to Sound																
1 - Auditory Startle																
0 - None																
<b>VISUAL FUNCTION SCALE</b>																
5 - Object Recognition *																
4 - Object Localization: Reaching *																
3 - Visual Pursuit *																
2 - Fixation *																
1 - Visual Startle																
0 - None																
<b>MOTOR FUNCTION SCALE</b>																
6 - Functional Object Use *																
5 - Automatic Motor Response *																
4 - Object Manipulation *																
3 - Localization to Noxious Stimulation *																
2 - Flexion Withdrawal																
1 - Abnormal Posturing																
0 - None/Flaccid																
<b>OROMOTOR/VERBAL FUNCTION SCALE</b>																
3 - Intelligible Verbalization *																
2 - Vocalization/Oral Movement																
1 - Oral Reflexive Movement																
0 - None																
<b>COMMUNICATION SCALE</b>																
2 - Functional: Accurate †																
1 - Non-Functional: Intentional *																
0 - None																
<b>AROUSAL SCALE</b>																
3 - Attention																
2 - Eye Opening w/o Stimulation																
1 - Eye Opening with Stimulation																
0 - Unarousable																
<b>TOTAL SCORE</b>																

Denotes emergence from MCS<sup>2</sup>  
Denotes MCS \*

Construct Validity	IRR	TRR	IC	Sens PPV	Spec NPV
Yes	Yes	Yes	Yes	No	No
GCS/DRS					

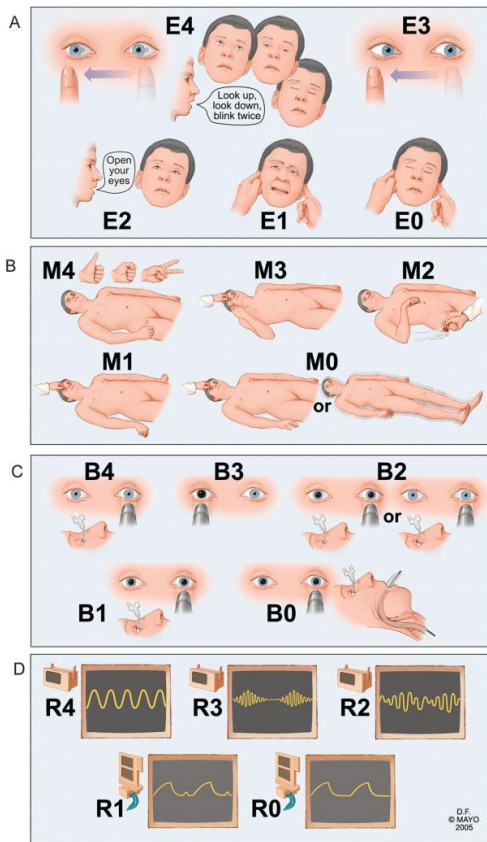
*Giacino JT, Kalmar K, Whyte J. The JFK Coma Recovery Scale- Revised: Measurement characteristics and diagnostic utility. Arch Phys Med Rehabil, 2004;85(12): 2020-2029.*

# CRS-R Applications

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- ◆ Evaluation of treatment effectiveness
  - ◆ Amantadine hydrochloride (*Schnakers, et al., 2008*)
  - ◆ Deep brain stimulation (*Schiff, et al., 2007*)
- ◆ Correlation of behavioral findings with functional neuroimaging measures
  - ◆ PET (*Schnakers, et al., 2008*)
  - ◆ fMRI (*Giacino, et al., 2006, Schiff et al., 2005*)
- ◆ Outcome prediction during rehab (*Thompson, et al., 1999; Giacino, et al., 1991*)
- ◆ Comparison of functional outcome between VS and MCS (*Giacino, et al., 1997*)

# Full Outline of Unresponsiveness (FOUR)



## FOUR Score

### Eye Response

- 4 Eyelids open or opened, tracking or blinking to command
- 3 Eyelids open but not tracking
- 2 Eyelids closed but opens to loud voice
- 1 Eyelids closed but opens to pain
- 0 Eyelids remain closed with pain

### Motor Response

- 4 Thumbs up, fist, or peace sign to command
- 3 Localizing to pain
- 2 Flexion response to pain
- 1 Extensor posturing
- 0 No response to pain or generalized myoclonus status epilepticus

### Brainstem Reflexes

- 4 Pupil and corneal reflexes present
- 3 One pupil wide and fixed
- 2 Pupil or corneal reflexes absent
- 1 Pupil and corneal reflexes absent
- 0 Absent pupil, corneal, and cough reflex

### Respiration

- 4 Not intubated, regular breathing pattern
- 3 Not intubated, Cheyne-Stokes breathing pattern
- 2 Not intubated, irregular breathing pattern
- 1 Breathes above ventilator rate
- 0 Breathes at ventilator rate or apnea

Construct Validity	IRR	TRR	IC	Sens PPV	Spec NPV
Yes	Yes	No	Yes	No	No
GCS/ Rankin					

*Wijdicks EFM, Bamlet WR, Maramattom BV, et al. Validation of a new coma scale: the FOUR score. Ann Neurol 2005, 58: 585-593.*

# FOUR Applications

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- ◆ Prediction of in-hospital mortality (*Wijdicks, et al., 2005*)
- ◆ Early identification of locked-in syndrome (*Wijdicks, et al., 2005*)

# Sensory Modality Assessment and Rehabilitation Technique

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Construct Validity	IRR	TRR	IC	Sens PPV	Spec NPV
Yes	Yes	Yes	No	No	No
MD Dx/ Rancho/ WNNSP					

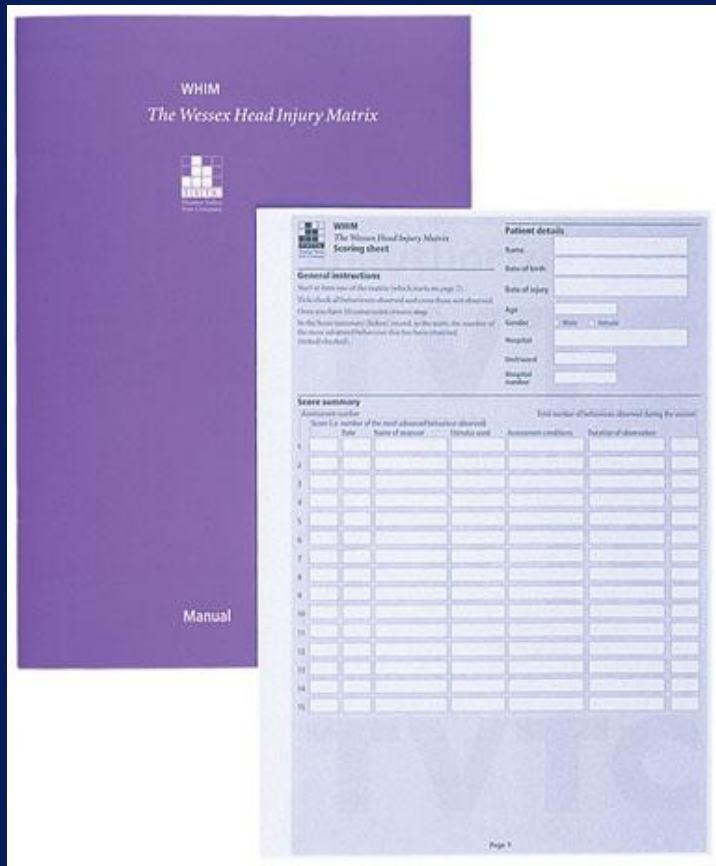
*Gill-Thwaites H, Munday R. The sensory modality assessment rehabilitation technique: A valid and reliable assessment for VS and MCS patients. Brain Injury 2004;18(12):1255-1270.*

# SMART Applications

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- ◆ Prediction of emergence from VS (*Wilson, et al., 2000; Wilson, et al., 1996*)
- ◆ Evaluation of treatment effectiveness
  - ◆ Sensory stimulation (*Wilson, et al., 1996; Wilson, et al., 1991*)

# Wessex Head Injury Matrix



Construct Validity	IRR	TRR	IC	Sens PPV	Spec NPV
Yes	Yes	Yes	No	No	No
GCS/GLS					

*Shiel A, Horn A. Clin Rehabil 2000;14(4):408*

# WHIM Applications

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- ◆ Diagnostic tool used in now-famous case of the “thinking” VS patient reported by in *Science* (Owen, et al., 2007)
- ◆ Correlation of electrophysiologic measures with behavioral signs of consciousness (Majerus, et al., 2005)
- ◆ Differential diagnosis of VS and MCS (Majerus, et al., 2001)
- ◆ Investigation of natural sequence of behavioral recovery from severe TBI (Shiel, et al., 2000)
- ◆ Outcome prediction
  - ◆ Recovery of consciousness (Majerus, et al., 2000)
  - ◆ Recovery of function (Shiel, et al., 2005)

# Selection Criteria for Neurobehavioral Rating Scales: *Validity*

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- ◆ Are existing diagnostic criteria for DOC represented within item content?
- ◆ Was scale tested in a representative sample with an adequate number of subjects?
- ◆ Was the scale compared to a diagnostic or prognostic reference standard?
- ◆ Is there evidence of a ceiling or floor effect?
- ◆ Is performance well-distributed across the possible range of scores?

# Selection Criteria for Neurobehavioral Rating Scales: *Reliability*

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- ◆ Are the administration procedures and scoring criteria operationally-defined?
- ◆ Interrater:
  - ◆ Were exams performed and scored independently by two different raters?
- ◆ Test-retest:
  - ◆ Did the same rater administer and score both exams?
  - ◆ Was the interval between exams specified?
- ◆ Were raters masked to diagnosis/each others scores?

# Individualized Quantitative Behavioral Assessment

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*To provide a valid and reliable means of assessing cognitive and/or behavioral capacities in patients with marked limitations in responsiveness*

*\*Designed for use with individual patients*

*Whyte et al. (1995)*

# Individualized Quantitative Behavioral Assessment

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- ◆ Based on single subject research design
- ◆ Clinical question individually tailored
- ◆ Stimuli and responses operationalized a priori
- ◆ Controls for observer and response bias
- ◆ Findings analyzed statistically ( $p=???$ )

# IQBA: Applications

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- ◆ Command-following
- ◆ Visual functions
- ◆ Communication ability
- ◆ Emotional responses
- ◆ Medication efficacy

# IQBA: Procedure

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- ◆ Question: Is right thumb movement occurring in response to command?
- ◆ Dependent measure: thumb movement
- ◆ Response criterion: right thumb elevates  $45^{\circ}$
- ◆ Conditions
  - ◆ Command: Raise your right thumb
  - ◆ Alternate command (Noise): Close your eyes
  - ◆ No command (Rest): No verbal prompt
- ◆ Analysis: Does thumb movement occur significantly more often following command relative to alternate command and rest? (2 x 3 chi square)

# Conclusion

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*“Much more is known about the psychometric properties of the scales that have been devised (for assessment of underarousal). Continued research in this area should yield a refinement of such scales, thereby permitting more precise quantification of the phenomenon of underarousal...However, the proliferation of varied “coma” scales has created a situation wherein it is difficult to compare results across research centers. Though some research has been conducted comparing various coma rating schemes, there is a need for continued research leading to wider acceptance of a single, standard measure of pathologic underarousal. Adoption of such a measure will...enable researchers and clinicians to develop a statistically based taxonomy.”*

*Stanczak, 1998*

# Looking Ahead

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American Congress of Rehabilitation Medicine

Disorders of Consciousness Task Force

Chair: Ron Seel, PhD

“Assessment Scales for Disorders of Consciousness:  
Evidence-Based Recommendations for Clinical  
Practice and Research”

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Obrigado!