Is anybody in there?

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Detecting consciousness without language comprehension or behavioural responses.

Ryan Scott, Ludovico Minati, Zoltan Dienes, Hugo Chritchley, Anil Seth

Why assess consciousness?

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Persistent Vegetative State?

Differential Diagnosis

Minimally Conscious State?

Locked-In Syndrome?

Current clinical practice

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Behavioural Assessment

e.g. Glasgow Coma Scale

	1	2	3	4	5	6
Eyes	Does not open eyes	Opens eyes in response to painful stimuli	Opens eyes in response to voice	Opens eyes spontaneously	N/A	N/A
Verbal	Makes no sounds	Incomprehensible sounds	Utters inappropriate words	Confused, disoriented	Oriented, converses normally	N/A
Motor	Makes no movements	Extension to painful stimuli	Abnormal flexion to painful stimuli	Flexion / Withdrawal to painful stimuli	Localizes painful stimuli	Obeys commands

Limited by dependence on

- **Volitional motor responses**
- **Language comprehension**

Both contribute to rates of misdiagnosis, estimated to be ~40% (Schnakers et al., 2009).

New approaches for non-responsive patients

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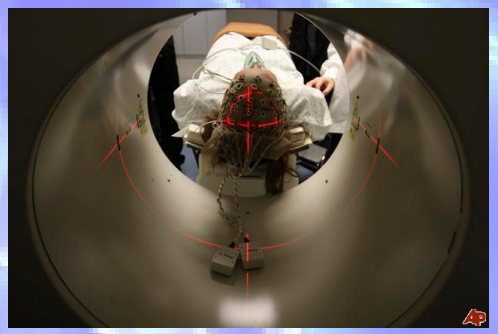
Awareness indicated by trace conditioning - using anticipatory electromyographic response to air-puff (Bekinschtein et al. 2009)

Conscious processing of auditory regularities - using ERP examining violation of local and global auditory regularities (Bekinschtein et al. 2009)



fMRI employed to index distinct patterns of brain activity associated with differences in the content of intentional visual imagery (Owen et al. 2006; Monti et al. 2010).

Limitations and clinical viability

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Behavioural Assessment

Reliance on language comprehension and motor responsiveness

Trace Conditioning using eye-blink

Eyes open, and sufficient integrity in efferent motor pathways

Auditory regularities using ERP

Technical complexity, and reliance on language comprehension

Visual imagery indexed using fMRI

Cost, equipment, complexity, and language comprehension

The Need

A technically simple, low-cost, bedside assessment method, reliant on neither language comprehension nor motor responsiveness.

The learned aversive contingency (LAC) procedure

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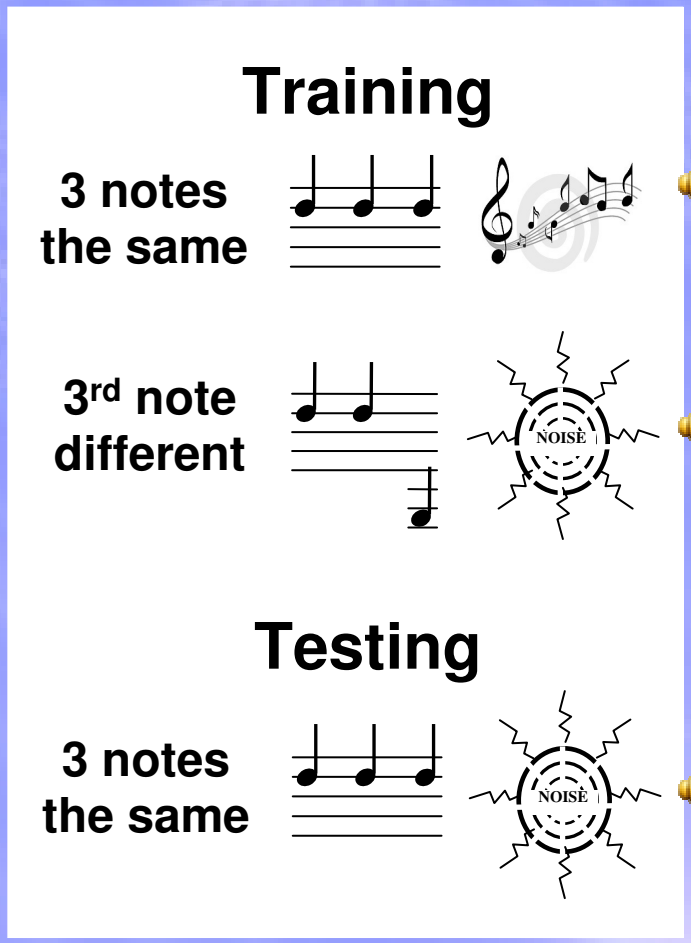
Training - 3 notes predict either a pleasant fanfare or a white noise according to a simple rule.

Testing - the rule is occasionally violated so the white noise may be unexpected.

Learning should be apparent in reduced sympathetic response (GSR) when white noise is predictable versus unpredictable.

PV patients exhibit significant GSR in response to white noise (Hildebrandt et al., 1998; Keller et al., 2007).



Testing the procedure

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30 healthy volunteers

- **Equipped with headphones**
- **Electrodes on index and middle fingers**

2 conditions

- **Attended Condition**
- **Unattended Condition**

Visual discrimination task

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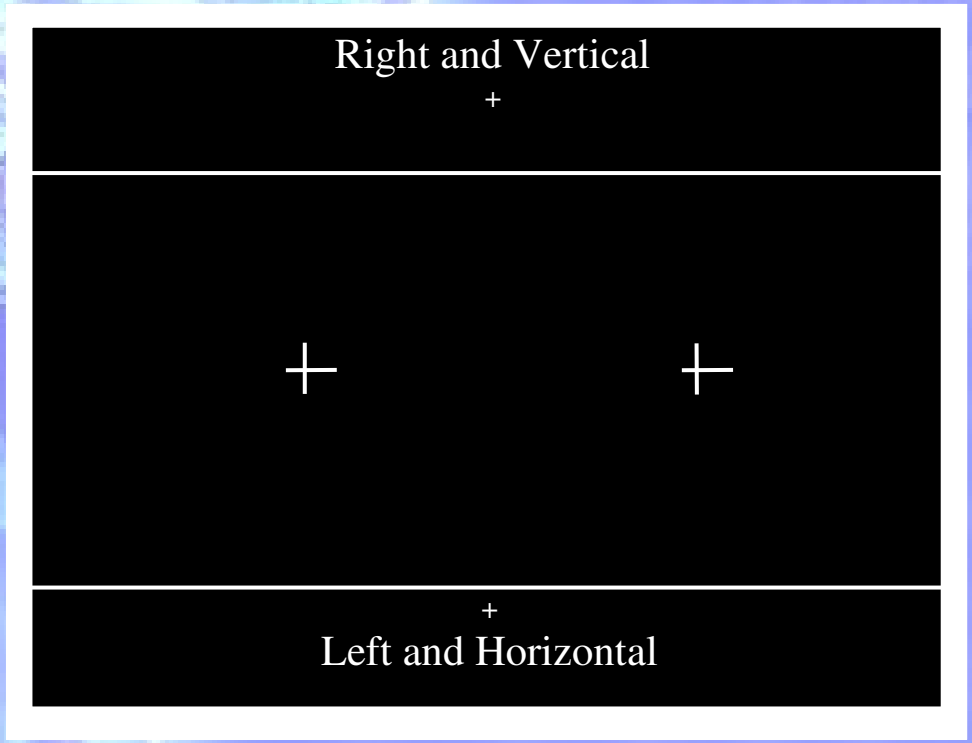

Testing the procedure

University of Sussex

30 healthy volunteers
- Equipped with headphones
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2 conditions
- Attended Condition
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Procedure
- 5 minutes training (20 trials)
- 5 minute rest
- 20 minute testing (64 trials)

Predicted differences in GSR

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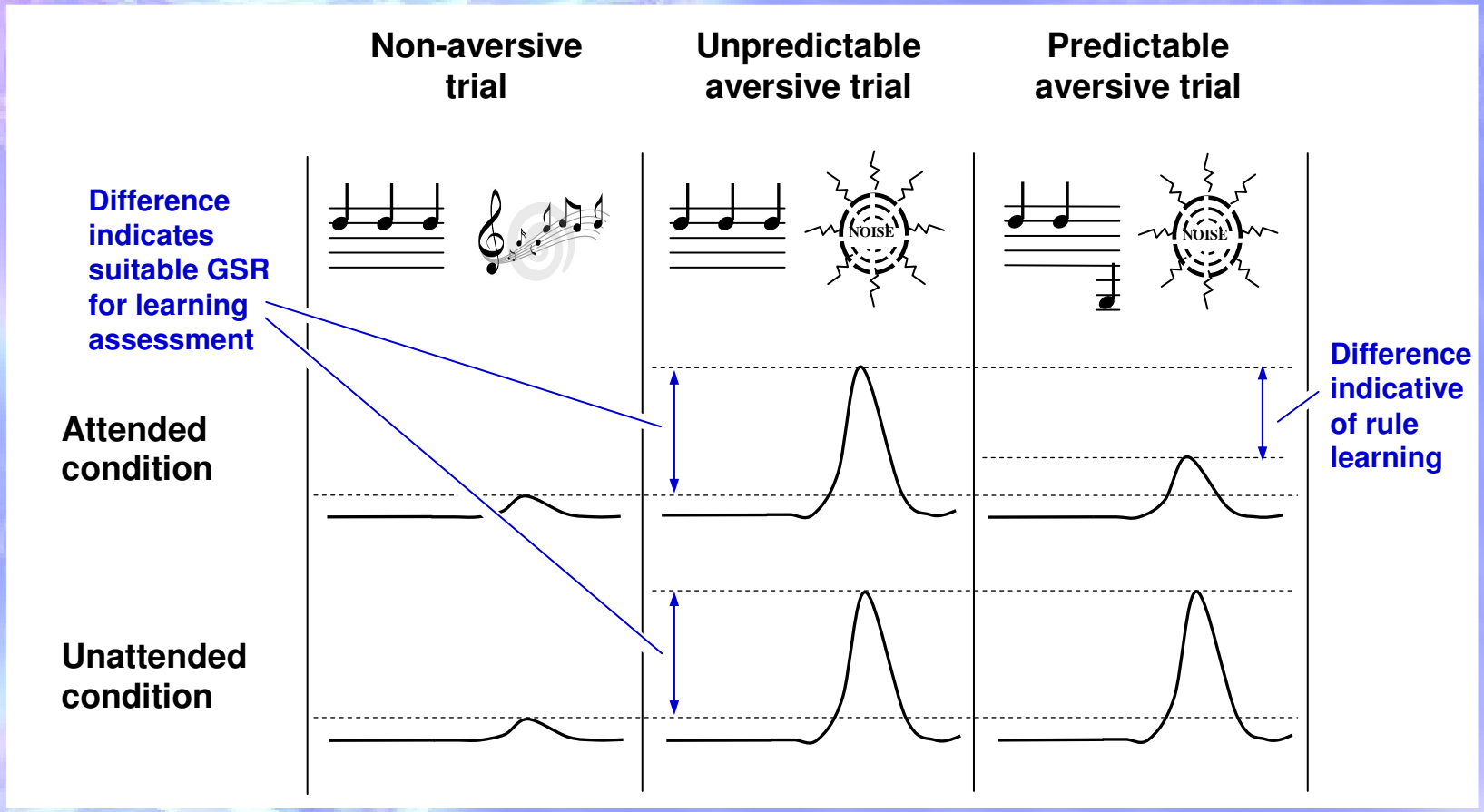

Evaluating learning through GSR

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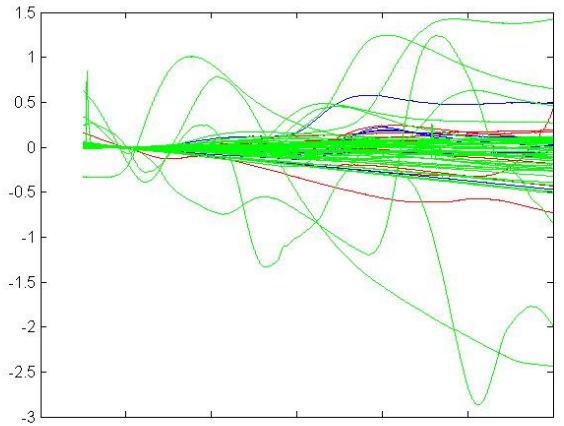
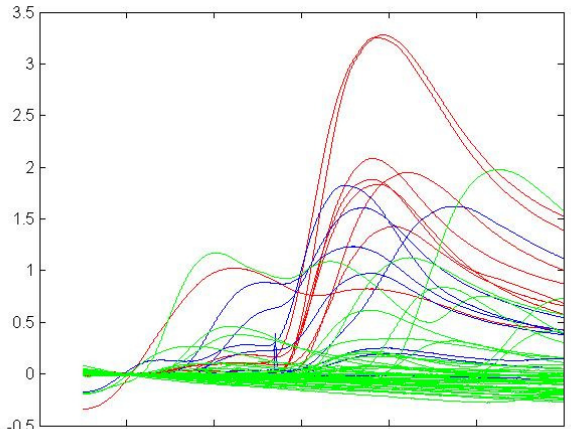
Test Trial Type

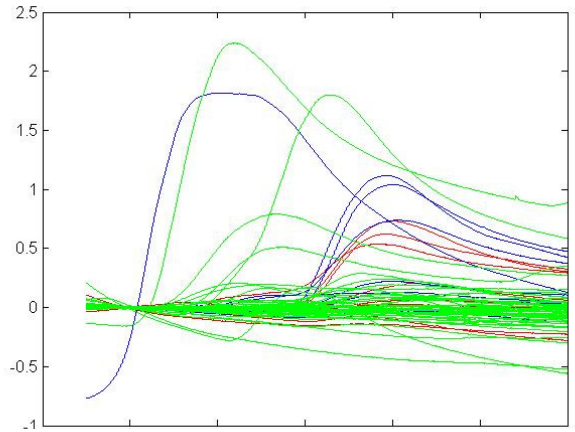
- Unpredictable Aversive
- Predictable Aversive
- Non-aversive



No reliable GSR



Attended condition



Unattended condition

Evaluating learning through GSR

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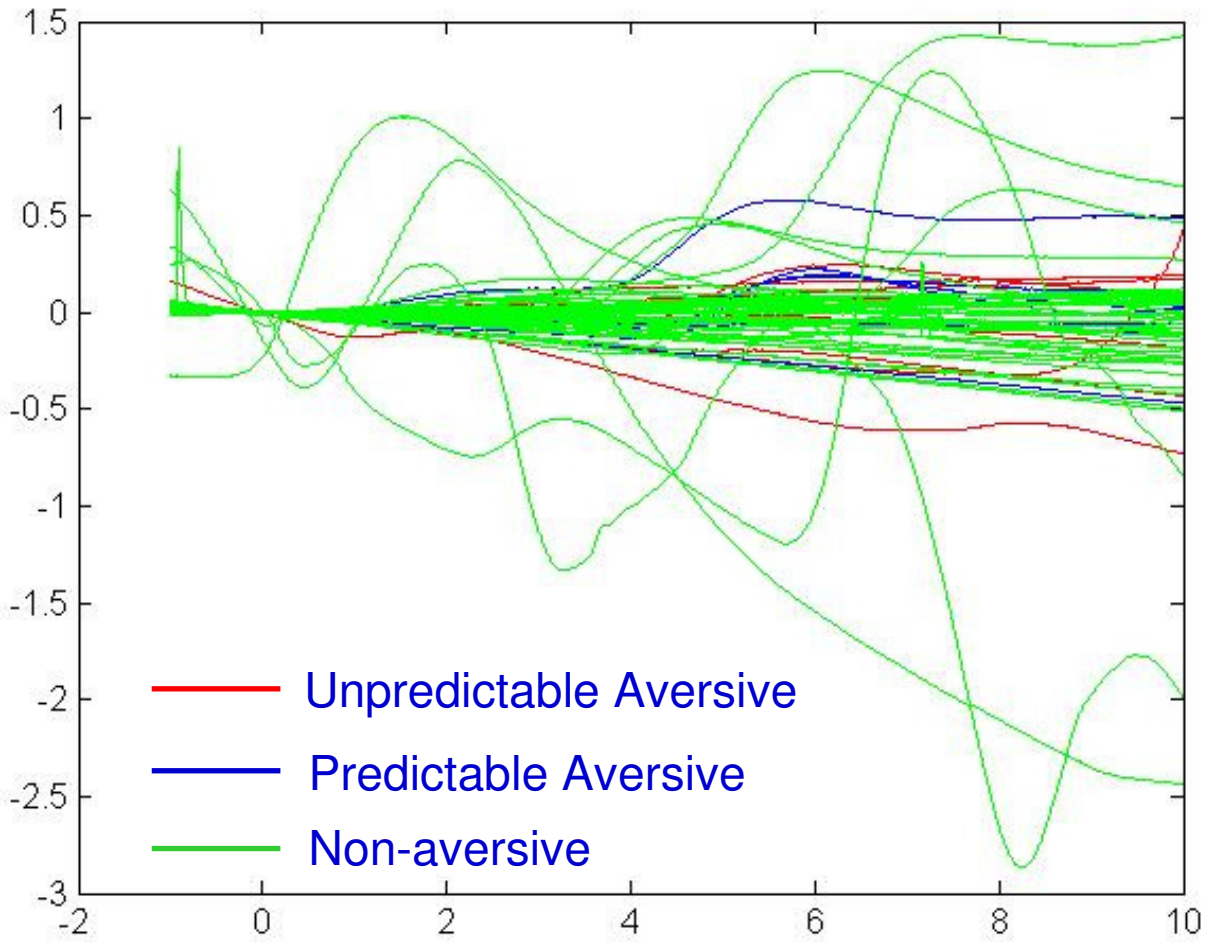

No reliable GSR

Evaluating learning through GSR

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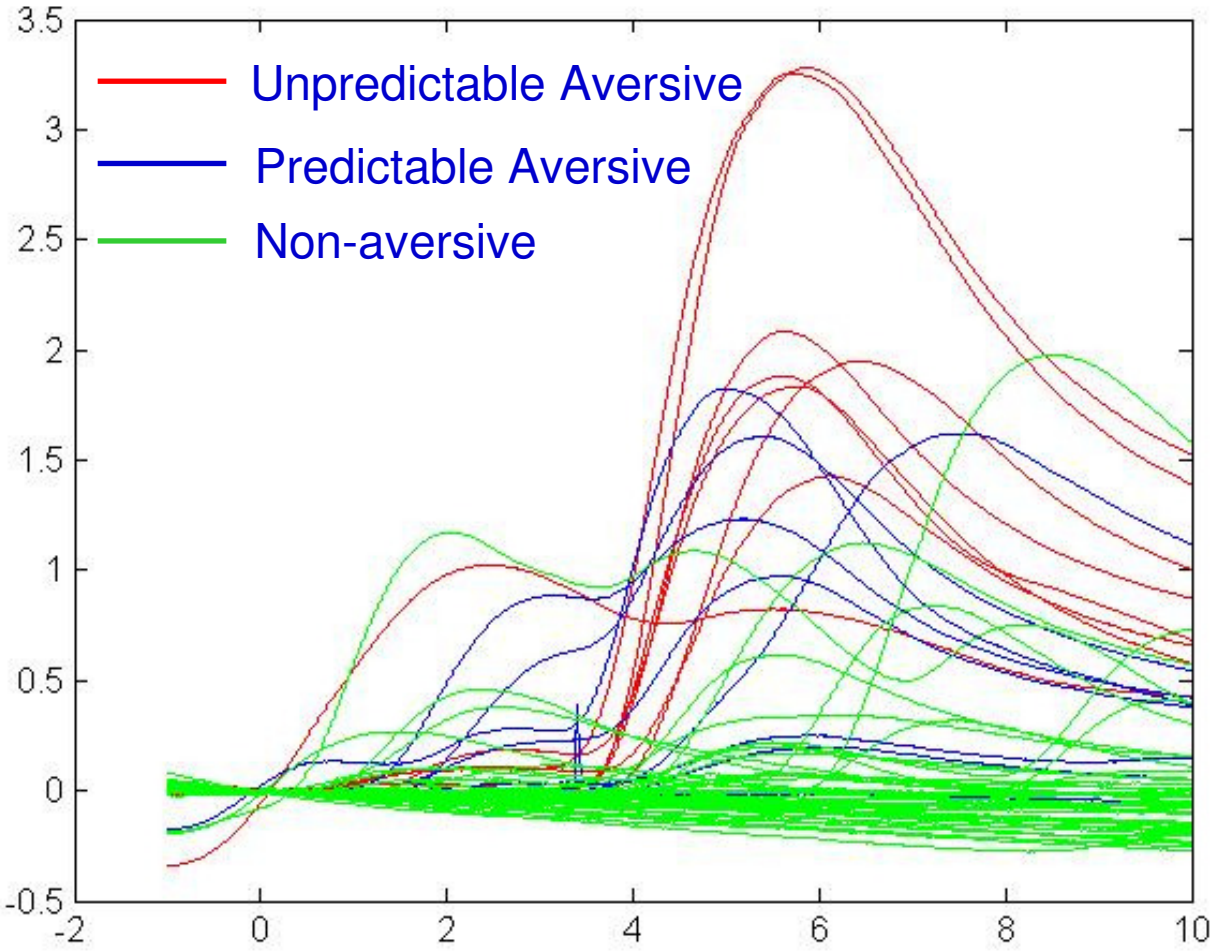

Attended condition

Evaluating learning through GSR

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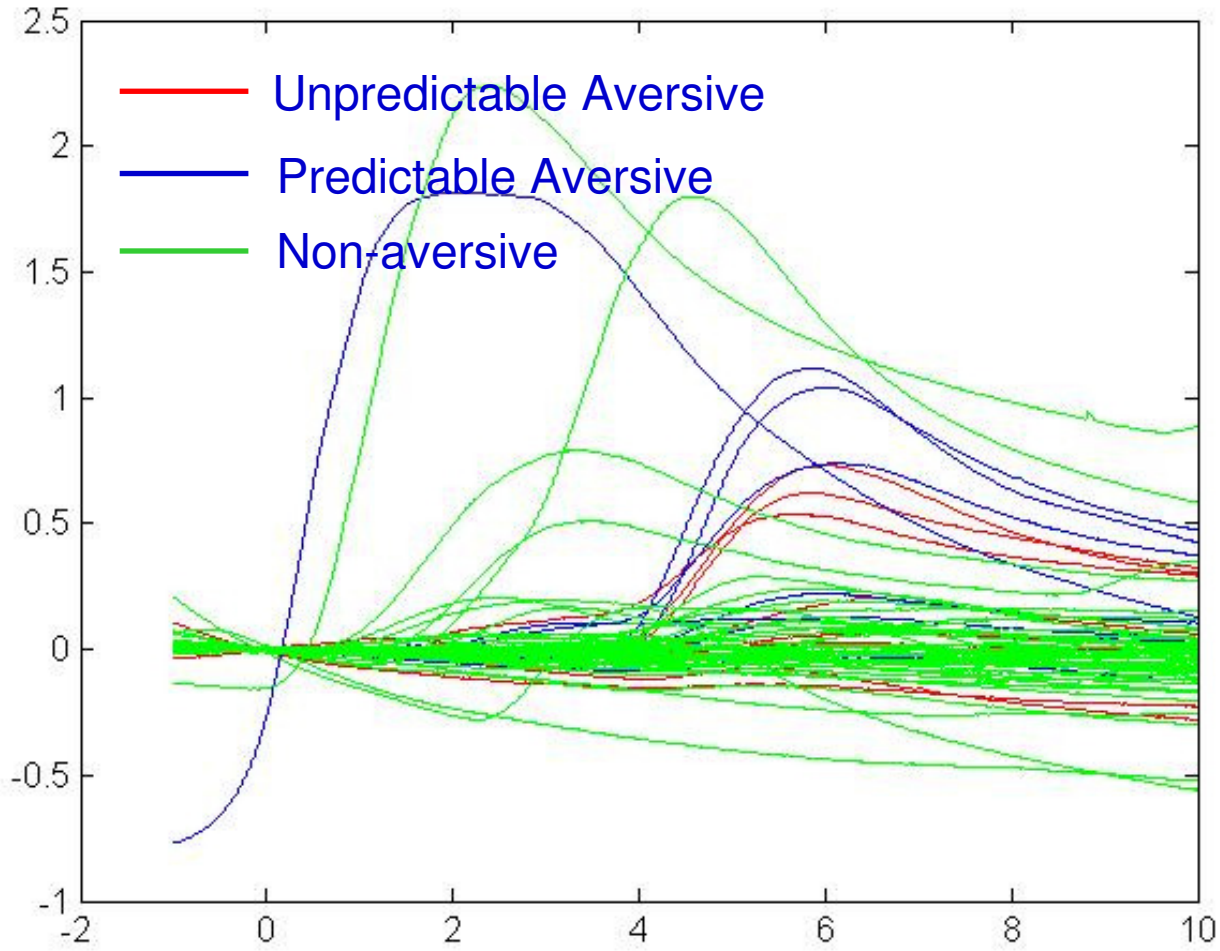

Unattended condition

Subjective reports of learning

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- All participants in the attended condition reported awareness of the rule and its subsequent violation.
- No participant in the unattended condition reported awareness of the rule.
- 6 participants failed to show a robust GSR response to the white noise
  - 5 in the unattended condition
  - 1 in the attended condition
- The remaining 24 participants (12 per condition) were assessed for learning based on GSR.

Conscious versus unconscious

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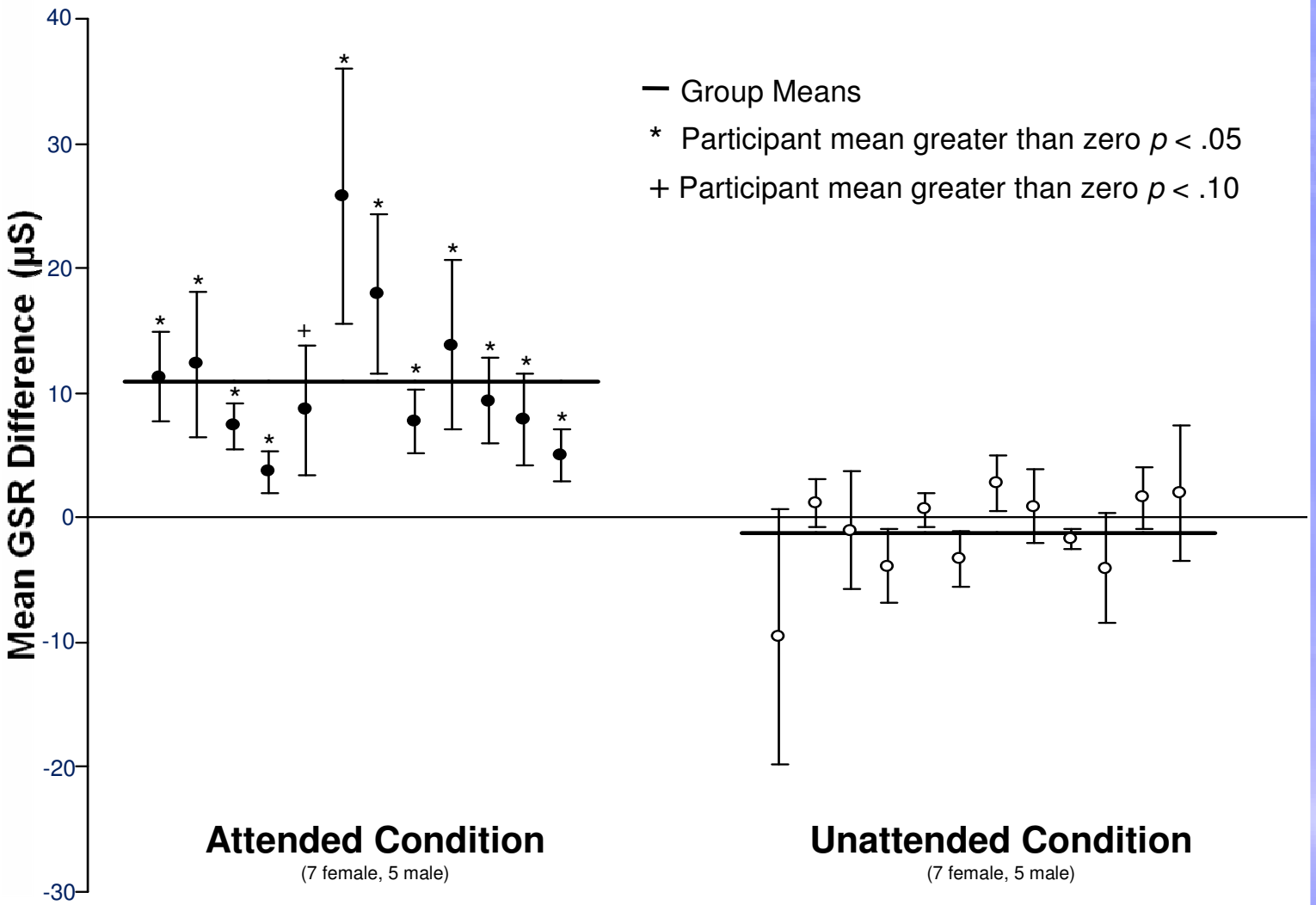

Summary

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The LAC procedure:

- Demonstrated learning without instruction of any kind
- Revealed learning from autonomic responses alone
- Accurately separated attending from non-attending participants
- Crucially, the method is technical straightforward

Limitations:

- It requires a sympathetic response, though it embeds a test that enables unsuitable patients to be identified
- It requires sufficiently preserved cognitive and attentional capacity to attend to the pattern

Conclusions

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- Strong conclusions cannot be drawn before clinical evaluation
- However, the LAC procedure appears to have the potential to offer a *clinically viable* means to extend assessment to patients lacking motor volition and language comprehension.

Terry Wallis regained awareness after spending almost 20 years in a minimally conscious state.

Thanks to my collaborators

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Anil Seth

Zoltan Dienes

Ludovico Minati

Hugo Critchley

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

University of Sussex
Sackler Centre for Consciousness Science

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Thanks for listening

Differential Diagnosis

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Table *Comparison of clinical features associated with coma, vegetative state, minimally conscious state, and locked-in syndrome*

Condition	Consciousness	Sleep/ wake	Motor function	Auditory function	Visual function	Communication	Emotion
Coma	None	Absent	Reflex and postural responses only	None	None	None	None
Vegetative state	None	Present	Postures or withdraws to noxious stimuli	Startle	Startle	None	None
			Occasional nonpurposeful movement	Brief orienting to sound	Brief visual fixation		Reflexive crying or smiling
Minimally conscious state	Partial	Present	Localizes noxious stimuli	Localizes sound location	Sustained visual fixation	Contingent vocalization	Contingent smiling or crying
			Reaches for objects	Inconsistent command following	Sustained visual pursuit	Inconsistent but intelligible verbalization or gesture	
			Holds or touches objects in a manner that accommodates size and shape				
			Automatic movements (e.g., scratching)				
Locked-in syndrome	Full	Present	Quadriplegic	Preserved	Preserved	Aphonic/Anarthric	Preserved