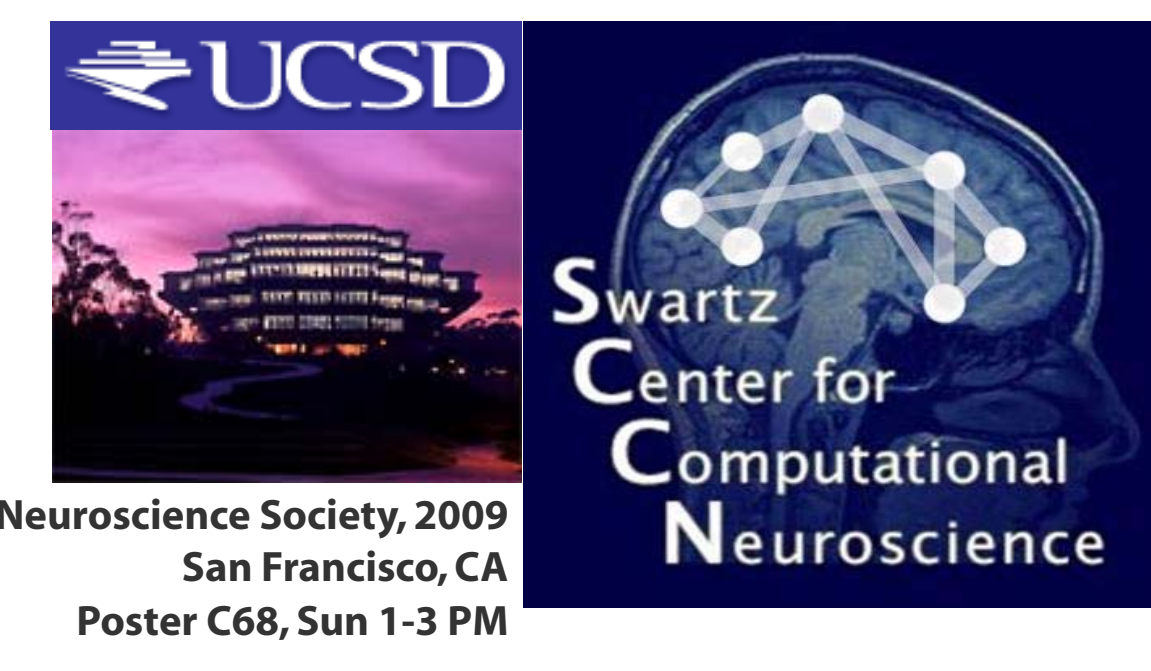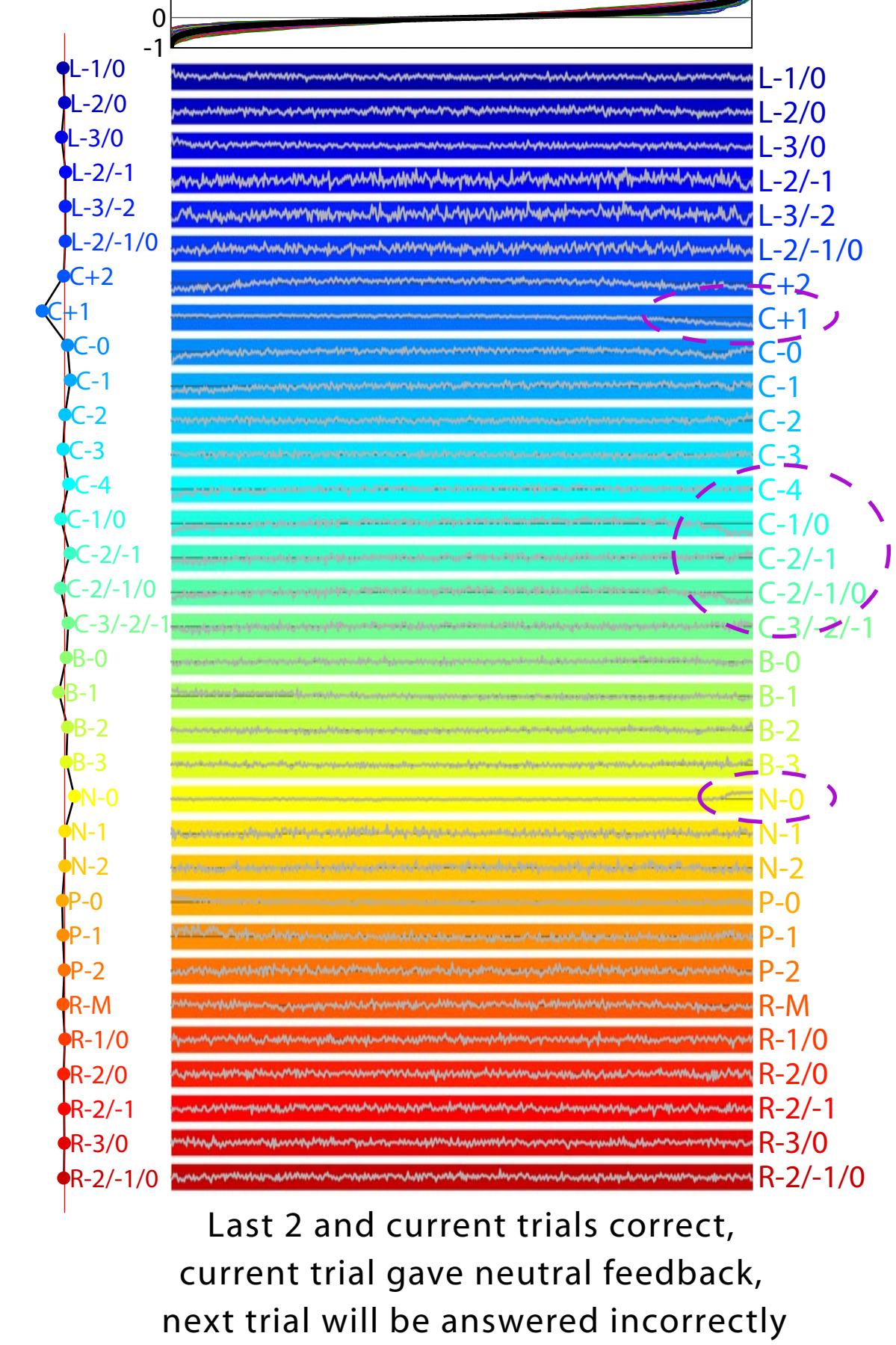# Associating event-related brain dynamics with event context

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OBJECTIVES

1. Discover context-dependent variabilities in EEG activities by blind decomposition of single-trial log **spectral variations** augmented by **context vectors** answering questions about the **context** of each trial -- past, current, and/or future events (stimuli, behavior, outcomes, etc).

2. Identify complex relationships between EEG data dynamics and subject experience, behavior, and information processing.

3. Find clusters of **independent component** context factors **across subjects.**

BACKGROUND

*The brain functions to meet **challenges posed by events** which are ever varying ...*

TASK

Match

Non-match

Two-back with feedback continuous performance task

`+  B  H  B^R  F^R`   Response / Auditory feedback ...

Twoback-with-Feedback

Subjects were presented a sequence of single letters whose durations varied based on subject performance (SOA ~1.5 s). Beginning with the third letter, subjects responded to each letter, specifying with a right or left thumb press whether the current letter was the same as the one presented two before. An auditory feedback signal at letter offset told the subject of whether their answer was correct or wrong. 850 ms later, the next letter was presented. Correct responses added 1 cent, and incorrect responses or failures to respond deducted 1 cent from the subject's performance bonus. After 20 percent of correct responses, a different feedback tone signaled a larger (5 cent) 'bonus.' Similarly, following 10 percent of incorrect responses another tone signaled a larger (5 cent) 'penalty'. Finally, in 6 percent of trials, a 'neutral' feedback signal withheld performance feedback.

One trial

Letter presentation — Response (360 ± 50 ms) — Auditory feedback — Letter presentation

600 ± 100 ms   850 ms
1450 ± 100 ms

CONTEXTS

Sample trial sequence:

... Trial -2 ...   Trial -1 ...   Trial 0 ...   Trial +1 ...
L R FB   L R FB   L R FB   L R FB
NM Lt Wr   M Rt Wr   NM Lt C   M Rt C
Non-Match / Left button / Wrong   Match / Right button / Wrong   Non-Match / Left button / Correct   Match / Right button / Correct

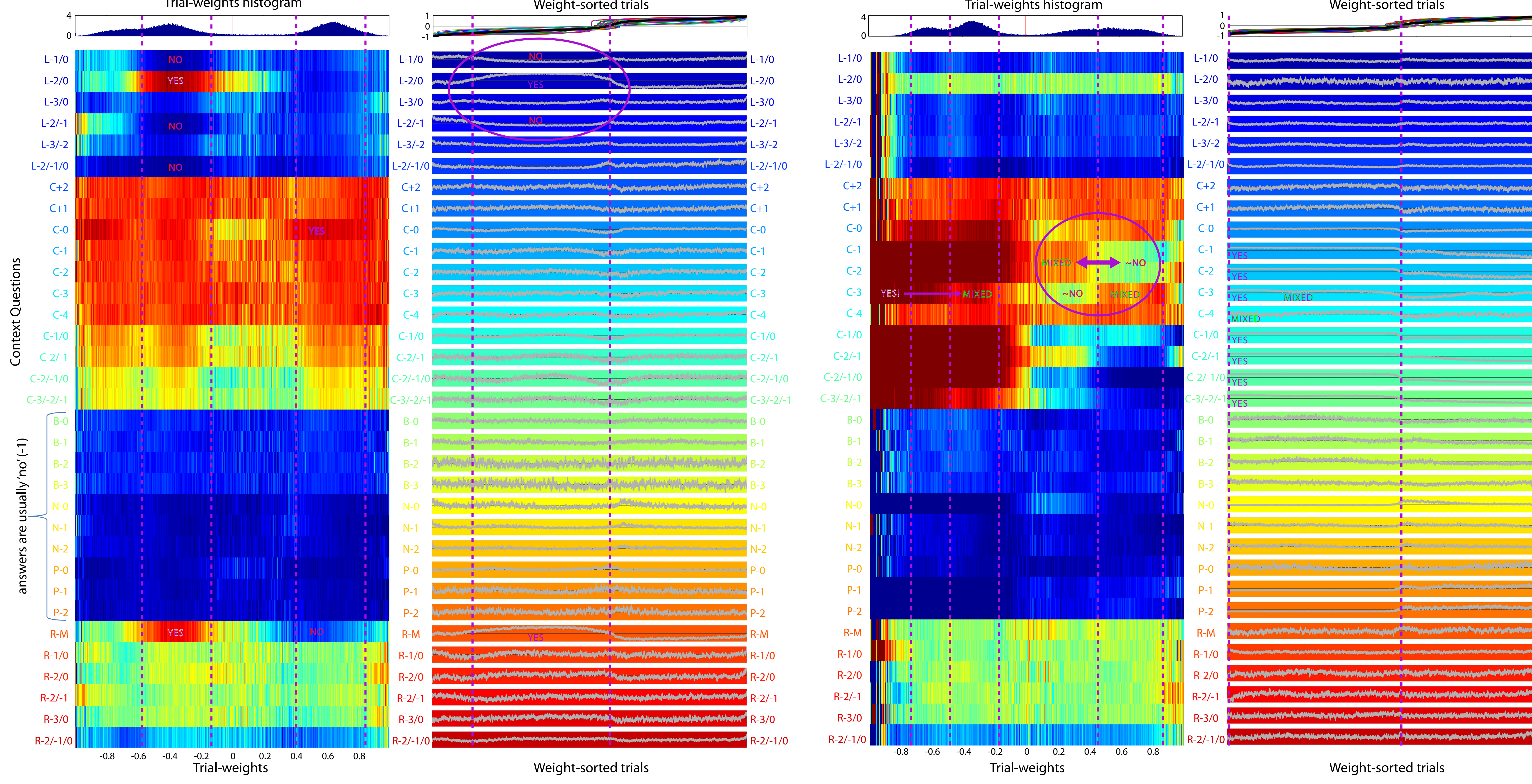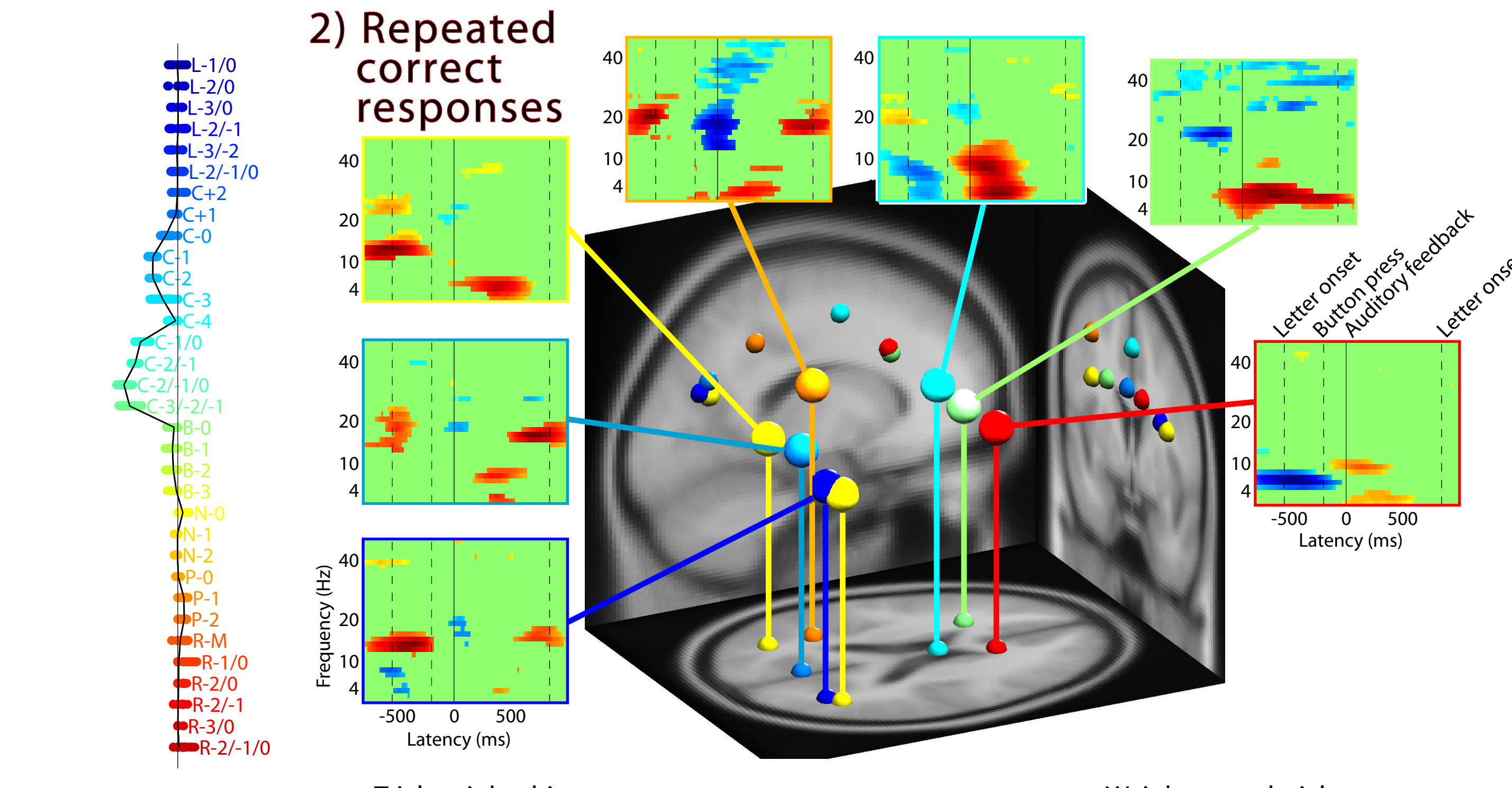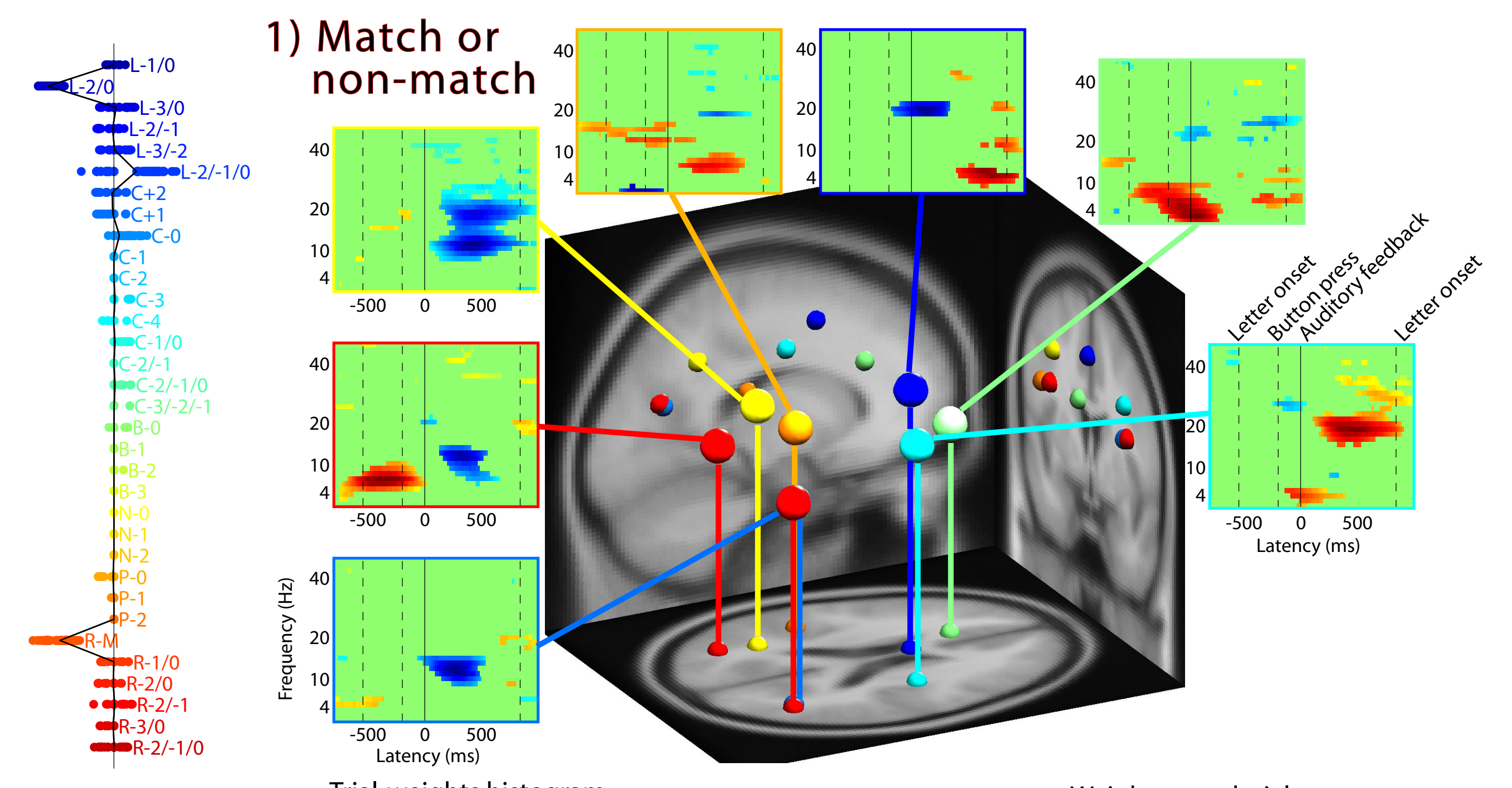*Some possible context dependencies:*

Does a characteristic log spectral change following the feedback tone depend on whether the preceding letter was a two-back **Match?**

Is a **Correct** response following a **Wrong** response associated with a characteristic log spectral power change that also partially predicts the performance in the succeeding (future) trial?

Trial-to-trial variations in event-related log power spectral perturbations following auditory feedback tones in this task may depend not only on the task significance of the current stimulus or the immediately preceding letter but on the combination of past performance, manual response history and the letter sequence, among other known and unknown variables. Log spectral changes following the feedback might also predict subject performance in future letter trials. Clearly there are many possible such context dependencies.
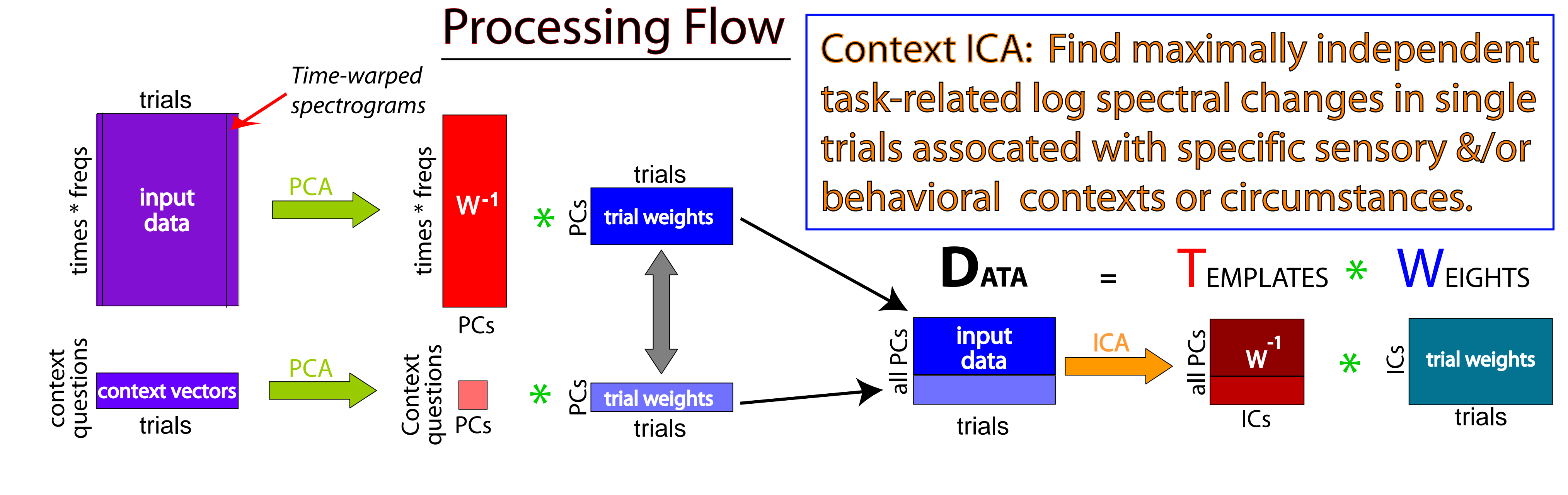
Context ICA (xICA) separates trial-to-trial spectral variability into a (log) linear mixture of active context dependencies.

Each context 'question' at right is answered with either a 1 for affirmative or a -1 for trials in which the answer is negative. This matrix is then used in the 'context data' matrix shown in the schematic decomposition above.

1) Match or non-match

Frequency (Hz) / Latency (ms)

Letter onset / Button press / Auditory feedback / Letter onset

Trial-weights histogram   Weight-sorted trials

2) Repeated correct responses

Frequency (Hz) / Latency (ms)

Letter onset / Button press / Auditory feedback / Letter onset

Trial-weights histogram   Weight-sorted trials

Trial-weights: -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8

Context Questions / answers are usually 'no' (-1)

3) Future incorrect response

Last 2 and current trials correct, current trial gave neutral feedback, next trial will be answered incorrectly

CONTEXT QUESTIONS

Current Letter = One-Back Letter ?
Current Letter = Two-Back Letter ?
Current Letter = Three Back Letter ?
One-Back Letter = Two Back Letter ?
Two-Back Letter = Three-Back Letter ?
Current Letter = One- and Two-Back Letters ?
Trial After Next Correct ?
Next Trial Correct ?
Current Trial Correct ?
One-Back Trial Correct ?
Two-Back Trial Correct ?
Three-Back Trial Correct ?
Four-Back Trial Correct ?
Current and One-Back Trials Correct ?
One- and Two-Back Trials Correct ?
Current, One-, and Two-Back Trials Correct ?
One-, Two- and Three-Back Trials Correct ?
Current Feedback Bonus-Correct ?
One-Back Feedback Bonus-Correct ?
Two-Back Feedback Bonus-Correct ?
Three-Back Feedback Bonus-Correct ?
Current Feedback-Neutral ?
One-Back Feedback-Neutral ?
Two-Back Feedback-Neutral ?
Current Trial Penalty-Wrong ?
One-Back Penalty-Wrong ?
Two-Back Penalty-Wrong ?
Current Trial Response: 'Match' ?
Current Trial Response = One-Back Response ?
Current Trial Response = Two-Back Response ?
One-Back Response = Two-Back Response ?
Current Trial Response = Three-Back Response ?
Current Trial Response = One- and Two-Back Response ?

Processing Flow

Time-warped spectrograms

times * freqs — input data →PCA→ times * freqs W⁻¹ (PCs)

context questions — context vectors →PCA→ Context questions (PCs)

trial weights (PCs) * trial weights (PCs)

Context ICA: Find maximally independent task-related log spectral changes in single trials associated with specific sensory &/or behavioral contexts or circumstances.

$D_{ATA} = T_{EMPLATES} * W_{EIGHTS}$

all PCs: input data →ICA→ all PCs W⁻¹ (ICs) * ICs trial weights

SUMMARY

>> Traditional methods of EEG analysis either **ignore** trial-to-trial variability or evaluate only a small number of **planned comparisons** (Ex: right vs. wrong). However, functional relationships of EEG activity to behavior and experience may not all be easily predicted.

>> Context ICA (xICA) decomposition separates the principal single-trial variability in the data into a trial mean (ignored here) plus a weighted mixture of trial-to-trial differences linked to various context factors including both simple, expected contrasts (Ex: correct vs. incorrect) as well as more complex, less expected factors.

>> xICA finds dependencies between continuous (EEG log spectral) data and discrete binary [yes,no] variables -- since between any two points -- e.g., [yes,no] -- a straight line may be drawn. Further exploration of the stability and limits of the method are required.