Single-trial EEG changes associated with specific behavioral contexts in a two-back task

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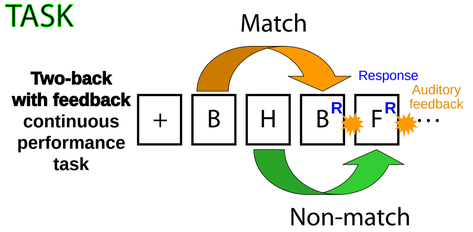
OBJECTIVES

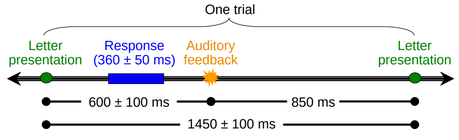
1. Discover context-dependent changes in EEG activities by blind decomposition of single-trial log spectrograms **plus** trial-identifying **context vectors** that answer a number of questions about past, current and/or future trial events (stimuli, behaviors, outcomes).

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

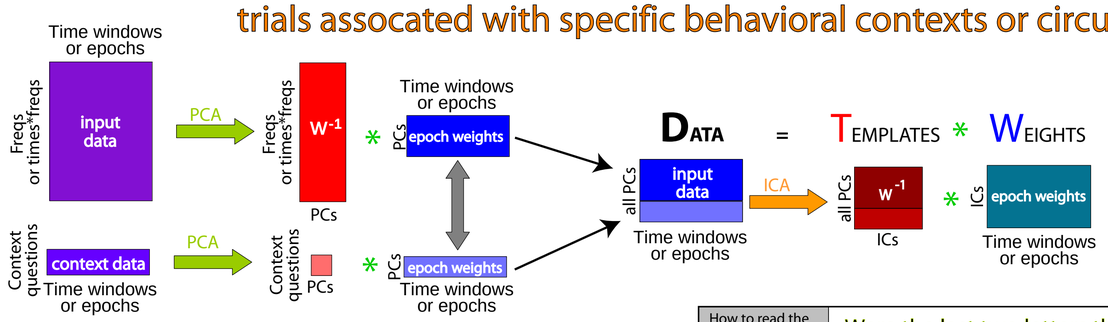
TASK



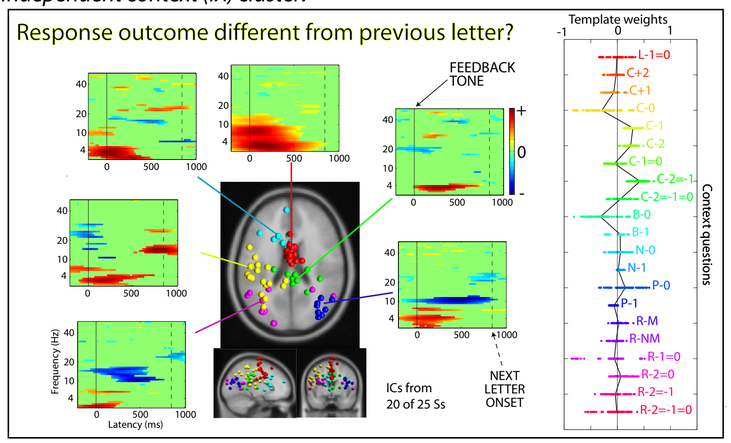
Subjects were presented sequential single letters whose durations varied based on subject performance (SOA ~1.5 s). Beginning with the third letter, subjects responded to each letter, specifying with a right or left thumb press whether the current letter was the same as the one presented two before. An auditory feedback signal at letter offset informed the subject of whether their answer was correct or wrong. After 850 ms, the next letter was presented. Correct responses added 1 cent, and incorrect or failures to respond deducted 1 cent from the subject's performance reward. Following 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'. In 6 percent of trials, a 'neutral' feedback signal gave no performance feedback.



Context ICA: find maximally independent task-related log spectral changes in single trials assocated with specific behavioral contexts or circumstances



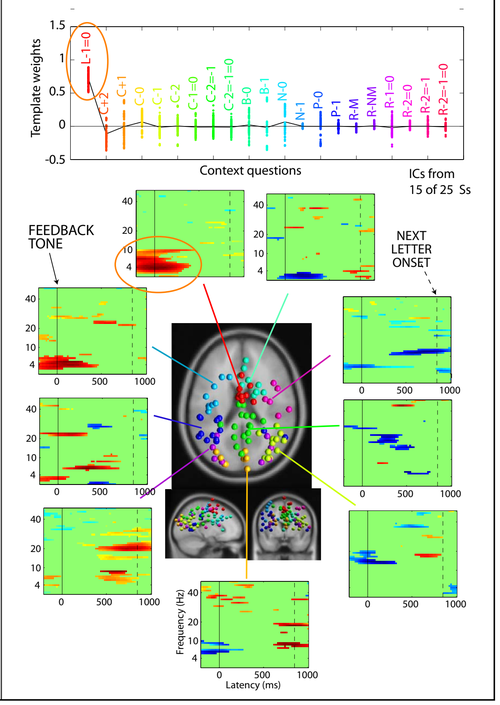
Independent context (IX) cluster:

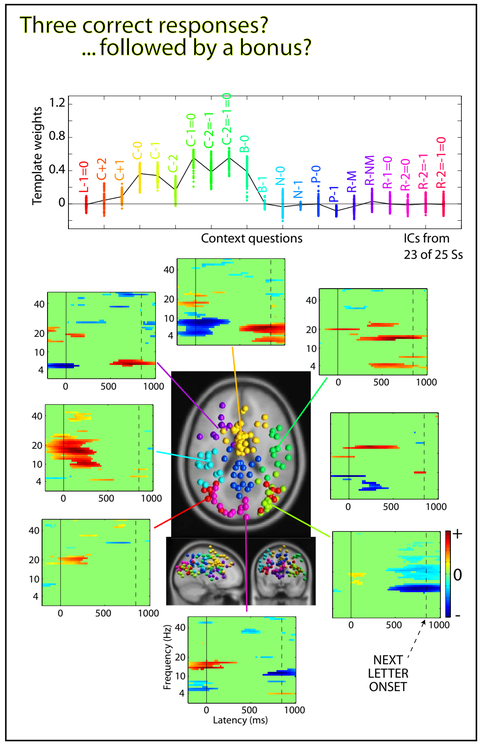


How to read the context question weights:

TRUE
+
0
-
FALSE

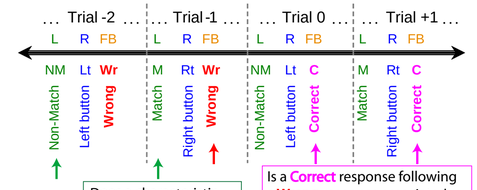
Note that the relationship betwen the context vector and the ERSP allow both to be inverted. For example (orange oval), central midline theta activity either **increased** when the last (current trial) and previous (Trial-1) letters **matched**, or **decreased** when these letters did **not** match.





CONTEXT

Sample trial sequence:



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?

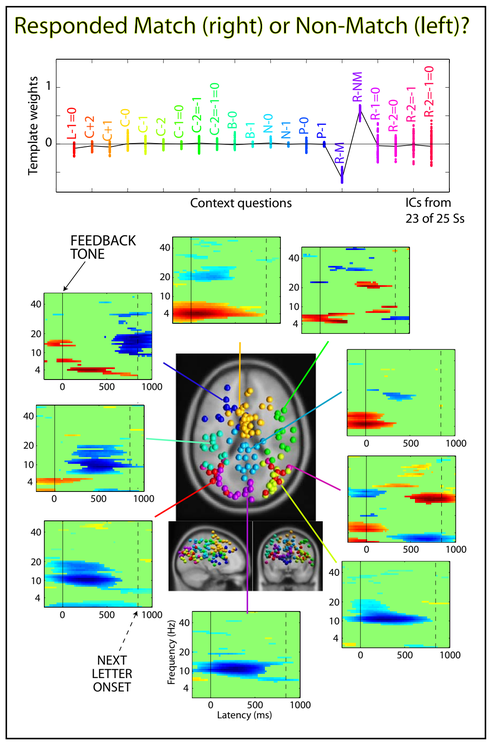
Trial-to-trial variations in event-related log power spectral perturbations following auditory feedback tones in this task may depend not only on the task significance of the current stimulus or the immediately preceding letter but on the combination of past performance, manual response history and the 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.

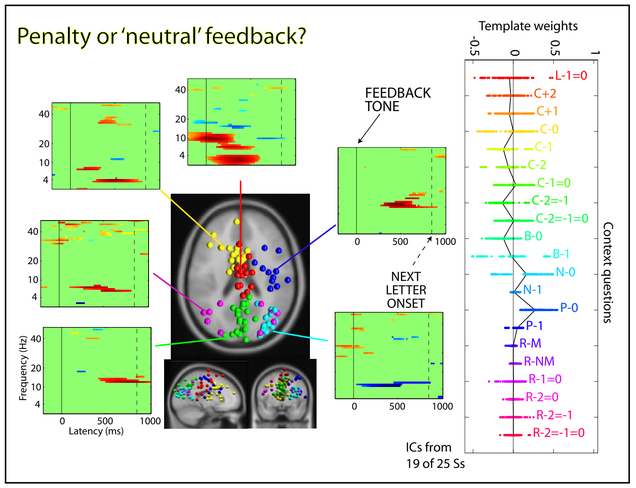
Context ICA (xICA) separates trial-to-trial spectral variability into a (log) linear mixture of active context dependencies.

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.

21 CONTEXT QUESTIONS

- Letter -1 = Letter 0?
- Feedback +2 = Correct?
- Feedback +1 = Correct?
- Feedback 0 = Correct?
- Feedback -1 = Correct?
- Feedback -2 = Correct?
- Feedback -1 = Feedback 0?
- Feedback -2 = Feedback -1?
- Feedback -2=Feedback -1= Feedback 0?
- Feedback 0 = Bonus?
- Feedback -1 = Bonus?
- Feedback 0 = Neutral?
- Feedback -1 = Neutral?
- Feedback 0 = Penalty?
- Feedback -1 = Penalty?
- Response 0 = Match?
- Response 0 = Non-Match?
- Response -1 = Response 0?
- Response -2 = Response 0?
- Response -2 = Response -1
- Response -2=Response -1= Response 0?





SUMMARY

Traditional methods of EEG analysis either ignore trial-to-trial variability or evaulate only a small number of planned comparisons (ex: correct vs incorrect). However, the functional relationships of EEG activity to subject behavior and experience cannot necessarily be predicted.

Context ICA (xICA) decomposition separates the principal single-trial variabilities in the data into a trial mean (ignored here) plus a weighted mixture of trial-to-trial difference linked to various context factors that could include simple expected context dependencies (e.g., correct vs incorrect) or more complex or unexpected relationships.

xICA can find linear dependencies between continuous (EEG log spectral) data and discrete binary (yes/no) variables because between any two points (e.g., yes, no) a straight line may be drawn. Further exploration of the stability and limits of the method is needed.