March Madness: Behavioral, physiological, and neural effects of surprise during naturalistic sports viewing

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Agents use sophisticated event models to predict characteristics of their environments[1]. As events unfold over time, agents implicitly and rapidly adjust their **predictions** based on these models, which can produce feelings of surprise[2].

Surprise, or unsigned prediction error, tracks the difference between previous and current predictions[2-5]. According to Event Segmentation Theory **(EST)**, surprise can drive the segmentation of ongoing experience into distinct events[6-7]. Surprise can also trigger learning that updates subsequent predictions about the structure of the world[3,8], and it can benefit memory for immediately preceding events[4].

We used sports games to understand how surprise influences perceived event segmentation, memory, eye physiology, and neural activation patterns in humans.

Operationalizations:

Predictions: "win probability" metrics from an expert basketball analyst (https://kenpom.com/) updated after each change in possession

Surprise: absolute value of the derivative of the win probability time course. We also compute "signed" prediction error if the subject prefers which team wins.

Viewing phase

View 3 games | Recall 3 games

x 3

Recall phase

Basketball fans (subjects) watch the last 5:00 of 9 games from the men's 2012 NCAA tournament

Which team were you cheering for?

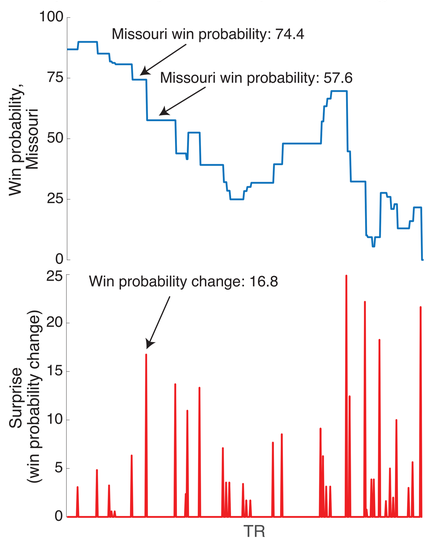
How enjoyable did you find this game?

1 Not enjoyable — 7 Very enjoyable

(2) Missouri vs. (15) Norfolk St.

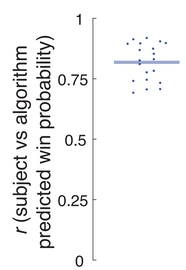
Recall this game in as much detail as possible.

Win probability and surprise, one game

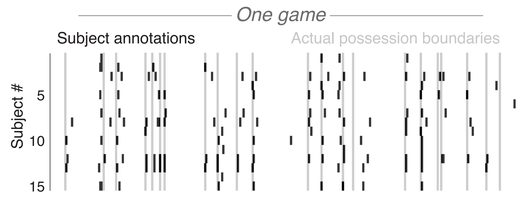


Subjects can accurately predict win probabilities

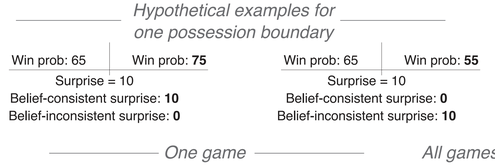
(4) Michigan 57
(13) Ohio 61
4:52 left
Possession: Ohio
How likely that Michigan wins?
0% 50% 100%

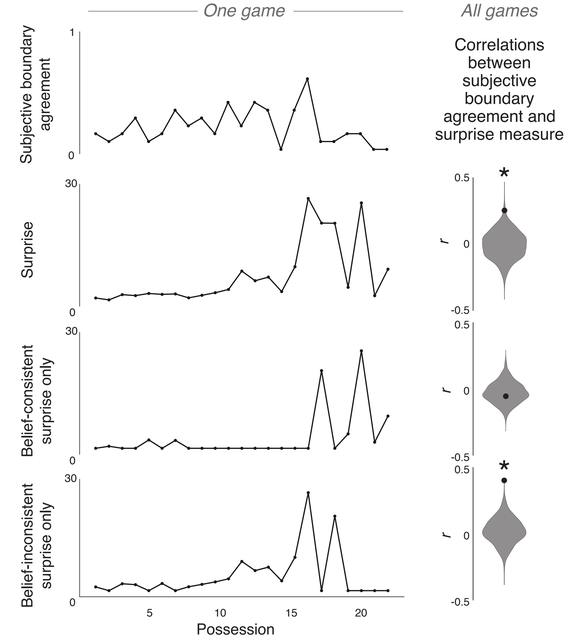


↑Surprise, ↑event segmentation



Segmentation correlated especially well with surprise opposing the current predominant belief



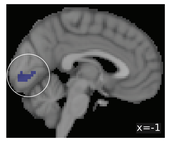


↑Surprise, ↑Hidden Markov Model (HMM) state changes

According to event segmentation theory (EST)[7], surprise triggers segmentation[9]. HMMs offer a data-driven way of finding segments by identifying moments when neural patterns shift. We predict surprise leads to state changes in vmPFC[10].

ROIs

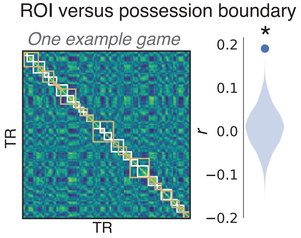
V1

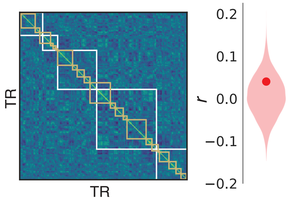


vmPFC

V1 state changes correlate with possession boundaries

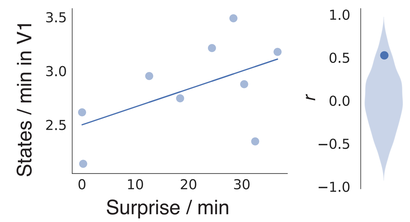
HMM state transition agreement in ROI versus possession boundary

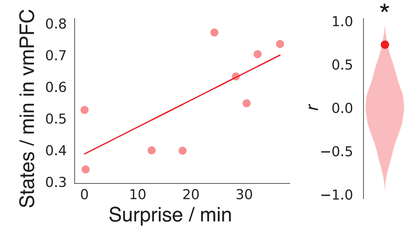




Surprise predicts vmPFC state changes across games

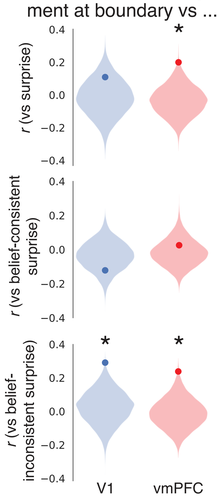
HMM states / min in ROI versus surprise / min in game





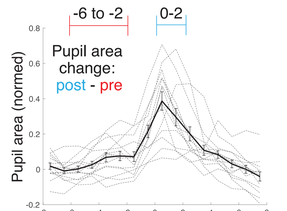
Surprise predicts vmPFC state changes across possessions

HMM state transition agreement at boundary vs ...

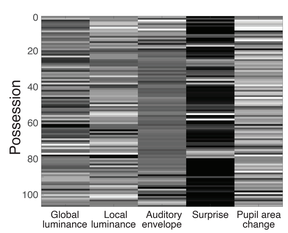


↑Surprise, ↑pupil area changes across possession boundaries

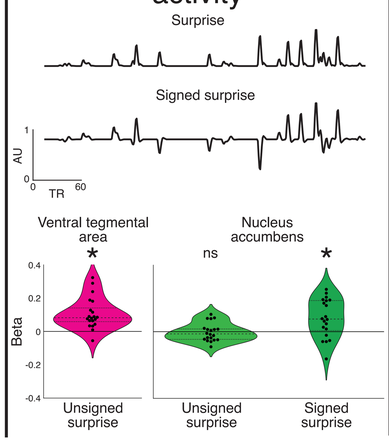
We regressed pupil area change across each possession boundary against the amount of surprise across that boundary. We also regressed out sensory factors like luminance and the auditory envelope from the broadcast.



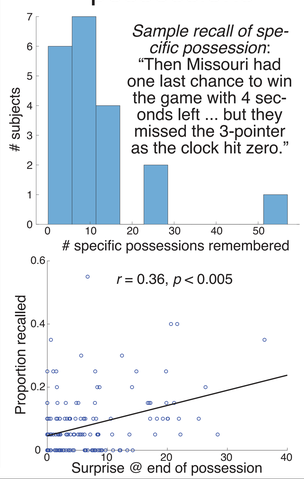
Surprise predicted pupil area change across the boundary ($p < 0.001$).



↑Surprise, ↑VTA activity, ↑signed surprise, ↑NAcc activity



↑Surprise, ↑memory for possessions



Take-home messages: • Surprise derived from real-world sports games map onto behavioral, physiological, and neural measures. • Results confirm predictions of EST: Possession changes with greater surprise => greater probability of HMM-identified state transition[1,4,9], and this was especially strong for surprise opposing the current predominant belief. • Surprise also predicted pupil dilation, VTA activity, and memory for possessions, and signed surprise (for games where subjects preferred one team over another) predicted NAcc activity.

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