Title: Local Field Potentials in Human Anterior Insula Encode Risk and Risk Prediction Error

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Abstract: Decisions about probabilistic rewards are informed not only by estimates of expected reward, but also by the risk surrounding these estimates. The expected risk of an option carries significance for decision processes, in that expected risk can modulate the propensity for choice above its expected reward alone. Just as estimates of reward can be updated via error signals during learning, predictions about the risk around these estimates can be correspondingly updated via risk prediction errors (risk PE). Previous fMRI work has demonstrated the presence of dissociated risk and risk PE signals in the anterior insula. Nonetheless, the fine-grained temporal dynamics of neural signals underlying fMRI correlates of expected risk and risk prediction error are not well characterised, nor is the spatial distribution of risk-related signals localised within the anterior insula. Here we elucidate the nature of underlying neural signals associated with risk-related computations in the anterior insula. We decompose the local field potential (LFP), observed by intracranial recordings in four human participants, and report oscillatory correlates of expected risk and risk PE. Using an established gambling task, we found that within localised populations in the anterior insula, trial-varying expected risk signals were positively correlated with high-frequency γ (>30 Hz) power, and emerged before the presence of reward- and risk-informative cues. After the onset of these informative cues, we found that risk PE signals correlated with slower oscillations in the α (8-12 Hz) and β (13-30 Hz) bands. These neural signatures of risk PE were more sustained in time, potentially allowing the risk PE signal to be employed for fast updating of expected risk. Importantly, these results shed light on both the multiplexed nature of risk-related neural signal in the insula, and converge with previous work to speak to the physiological bases of fMRI activity.