Response to Miller: "Broadband" vs. "high gamma" electrocorticographic signals

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In his Journal Club, Miller provides a cogent description of how researchers can use broadband signals in electrocorticographic (ECoG) recordings to estimate neuronal spiking without observing individual action potentials. The review brings up the important issue of whether broadband ECoG signals, which appear at all frequencies (*1, 2*), reflect the same physiological signal as "high gamma" oscillations, which are typically reported as occurring in the ~70–150-Hz range (*3–6*). Our research suggests that broadband ECoG activity is a non-oscillatory physiological signal. As we explain below, previous studies have measured broadband signals, but the results are often incorrectly described as "high gamma" oscillations.

Beginning with Crone et al. (*3*), a number of studies described ECoG power increases at ~70–150 Hz when a brain region was active. This pattern was called "high gamma" because it appeared to be a faster version of the well-studied gamma oscillation, which generally appears as a rhythmic signal at ~40 Hz (*7*). The use of the term "high gamma" implied that this faster signal reflected a true rhythmic oscillation. At the time this nomenclature appeared to be appropriate, because the evidence indicated that this activity was limited to a frequency band below ~150 Hz.

Subsequent studies examined the ECoG correlates of cortical activity using recording systems with faster sampling rates. These studies found that this signal was a broadband ECoG power increase that appeared simultaneously at all frequencies (*1, 2*), rather than being limited to a particular frequency band. Thus, the ECoG correlate of cortical activation was not a true oscillation, but instead was a broadband power increase that was caused by non-rhythmic synaptic activity. Because this broadband signal is non-oscillatory, we propose that future studies should refer to these phenomena as "broadband fluctuations" rather than as "high gamma oscillations."

We suggest that methodological differences caused the authors of earlier studies to describe broadband fluctuations as "high gamma" oscillations whereas later studies called them "broadband." Many of the earlier studies were unable to accurately examine ECoG activity above ~100–150 Hz because they used amplifiers that sampled at ~200–500 Hz (with anti-aliasing filters) and had a decreased signal-to-noise ratio at high frequencies (*8*). As a result, they did not observe the power increases at higher frequencies, leading them to describe this signal as being limited to the ~70–150-Hz "high gamma" band.

In practice, gamma oscillations (~30–70 Hz) can be difficult to distinguish from broadband fluctuations because both phenomena appear at overlapping frequency bands; both exhibit phase–amplitude coupling with theta (4–8 Hz) oscillations; and both correlate with neuronal spiking (*2, 4, 9, 10*). The 30–100-Hz "gamma" activity described by Whittingstall and Logothetis (*6*), which was mentioned in Miller's review, appears to be related to broadband fluctuations rather than gamma oscillations, because it did not exhibit some of the known properties of gamma oscillations, such as phase-locked spiking (*7, 9, 10*).

It is important to distinguish true ECoG oscillations from broadband fluctuations because the two phenomena imply distinct underlying physiological processes. Because it is primarily the high-frequency spectral information that differentiates broadband and narrowband activity, recording systems with high sampling rates are useful for distinguishing these two signals. Moving forward, a challenge for researchers will be to design advanced signal-processing methods for separating broadband signals from true oscillations.

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