COMMENTARY

Gamma Oscillations in a Bind?†

Ali Mazaheri and Rosanne Van Diepen

Department of Psychiatry, Academic Medical Center, University of Amsterdam, Amsterdam, Netherlands

†A commentary on: “Stimulus Dependence of Gamma Oscillations in Human Visual Cortex” by Hermes et al. 2014.

Address correspondence to Ali Mazaheri. Email: ali.mazah@gmail.com

Electrophysiological brain signals contain oscillatory activity in various frequency bands, such as delta (<2 Hz), theta (3–8 Hz), alpha (8–13 Hz), beta (18–25 Hz), and gamma (>30–Hz), which are believed to be produced by frequency-specific networks in the brain and are believed to map on to various aspects of cognition (Lakatos et al. 2007; Fries 2009; Schroeder and Lakatos 2009; Siegel et al. 2012).

Gamma oscillations have received particular attention over the last decade for their hypothesized role in mediating information transfer across the cortex (Tallon-Baudry et al. 1996; Tallon-Baudry and Bertrand 1999; Lachaux et al. 2005; Womelsdorf and Fries 2007). In particular, gamma synchronization, that is, the (phase) synchronization of neural firing within a cortical region, has been proposed to enable their effective communication (Fries 2005). To date, there have been a considerable number of high-profile studies supporting this hypothesis (Womelsdorf et al. 2007; Bosman et al. 2012; Siegel et al. 2012; Brunet et al. 2013).

However, a study by Hermes et al. in this issue of Cerebral Cortex raises critical new questions about the role of gamma oscillations in mediating neuronal communication. They find that oscillatory gamma activity (30–80 Hz) in the human visual cortex is only reliably induced by some stimuli, such as oriented gratings and only some natural images. While previous studies have shown some stimulus-dependent variability in the frequency and amplitude of gamma oscillations (Gieselmann and Thiele 2008; Ray and Maunsell 2010), this is the first study to show in humans that the gamma rhythm is simply completely absent for some stimuli. This finding directly challenges the notion that gamma oscillations are an essential and general prerequisite for visual processing.

Hermes et al. used electrocorticography (ECoG) to investigate the emergence of gamma band activity after the onset of different types of visual stimuli such as square wave gratings of varying frequencies, noise patterns, and pictures of faces and houses. Their rational was that “if” the gamma activity was a critical component of visual processing, “all” stimuli would induce some degree of gamma oscillations. However, they found that while gratings and pictures of select spatial patterns generated clear gamma activity, many types of stimuli did not evoke any gamma activity, including noise patterns and many pictures of faces and houses tested.

In addition to narrowband gamma oscillations (30–100 Hz), the authors examined broadband high-frequency activity (80–200 Hz). Broadband high frequency does not have a narrow peak in the spectrum and is considered a reflection of asynchronous activity instead of an oscillation such as gamma activity (Miller et al. 2009).

Previously research has found that the power of the narrow gamma oscillations to be negatively correlated with multiunit activity (i.e., total neural activity in the region) (Jia et al. 2011; Ray and Maunsell 2011), see Sedley and Cunningham (2013) for review. In contrast, multiunit activity and the power of broadband high-frequency oscillations have been found to be very highly correlated (Ray and Maunsell 2011). Although this suggests that these 2 types of signals stem from different underlying circuits (Manning et al. 2009; Miller et al. 2009; Ray and Maunsell 2011), they have not been consistently separated in previous studies.

Hermes et al. separated these 2 signals and found that, contrary to the stimulus specificity of the narrowband gamma oscillations, all visual stimuli induced broadband high-frequency responses. This would then implicate the broadband high-frequency activity to play a fundamental role in the processing of visual information, rather than the narrowband gamma. At first sight, the conclusions from Hermes et al. might seem in contradiction with an earlier study by Yuval-Greenberg et al. (2008). Yuval-Greenberg et al. were able to demonstrate quite unequivocally that the broadband gamma activity (30–100 Hz) previously attributed to the perceptual binding of several stimulus features did not originate from the visual cortex. Importantly, these results were acquired using scalp Electroencephalograph which is rather susceptible to high-frequency muscle artifacts. In contrast, the high-frequency activity in Hermes et al. was obtained using ECoG, which predominantly picks up activity from the areas of cortex that are very close to the electrode patch, and as such unlikely to be contaminated by artifacts from muscle activity.

The principle findings of Hermes et al. render the current theories about the role of narrowband gamma synchronization in facilitating information transfer across the brain incomplete at best. However, it should be noted that the principle of synchronization as a mechanism of information transfer is not really challenged here. It is possible to have synchronization still be an essential prerequisite for neural communication, with that the frequency band in which the synchronization occurs to be reliant on stimulus properties. This would mean that any new theories on the role of any oscillation in visual information processing now need to incorporate stimulus properties.

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Notes

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References


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