Hypnotic states induce high-frequency power changes [70-140 Hz] in the Default Mode Network

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Abstract: Hypnotic suggestion has been used clinically for hundreds of years, especially because of its efficacy in stress, anxiety and pain management [1-3]. At the phenomenological level, hypnosis is characterized by an enhancement of a broad range of normal states such as absorption, disengagement from the external environment, reduction of spontaneous thoughts, sensory responsivity and self-referential judgment [4]. Over the last few decades, an increasing number of functional neuroimaging studies has been performed in order to understand the neural substrates related to these different cognitive components [5-7]. In particular, recent works suggest that hypnosis produces alterations in the default mode network (DMN) [8], and specifically a reduction of brain activity in its anterior parts (ACC, medial and superior frontal gyri, left inferior and middle frontal gyri) [9-11]. Because these regions have been related to the sense of self and self-referential processing, a direct link is provided with specific experiential components of hypnosis. Nevertheless, while functional imaging studies allow for a precise spatial characterization of resting state networks, their fine-scale temporal dynamics remain elusive. A full understanding of the differential modulation of DMN subnetworks by hypnotic processes requires further evidence from electrophysiological recordings.

In the present study, our objective was to investigate the effects of hypnosis on ongoing brain activity using direct local field potentials at multiple fronto-temporal cortical locations. Taking advantage of invasive intracerebral recordings of epileptic patients undergoing a diagnostic evaluation in a presurgical context, we recorded in total from 690 cortical sites, including prefrontal, cingulate, limbic, temporal and parietal structures, while the patients were undergoing a hypnotic induction by an experienced hypnotherapist using a standardized script (Figure 3). In our analysis we

focused on the high-gamma power (HGP, 70-140 Hz) changes that was previously shown to reflect changes in DMN-activity [12]. Here we distinguished two distinct functional-anatomic components (MF: Medial Frontal/temporo-parietal Cortex Subsystem; MTL: Medial Temporal Lobe Subsystem) that converge on a midline core (MC, including the anterior medial prefrontal and posterior cingulate cortices) [8] (Figure 1-A). HGP changes were evaluated using a pre-hypnosis eyes-closed baseline to the period prior to the hypnotic induction (Figure 1-B). A across our populations of 9 implanted patients, our results show 1) a reduction of HGP in MF (Figure 2), possibly reflecting a reduction in self-referential cognitive activity, 2) increases in HGP in the hippocampal formation including entorhinal and parahippocampal cortices, presumably reflecting increased memory retrieval of autobiographic memories or imaginary scenarios; 3) increase of HGP at fronto-parietal locations of the attentional network indicating a progressive absorption during the hypnotic induction and 4) HGP changes in the amygdala suggesting changes in emotional processing. In sum, our findings indicate that hypnosis creates a distinctive and unique pattern of brain activation and deactivation that has a modulatory effect on regions processing explicit cognitive control, memory recall, emotional and attentional processing. Selective targeting of these changes may be used to improve outcome in psychotherapy, pain control or in learning and memory function [13].

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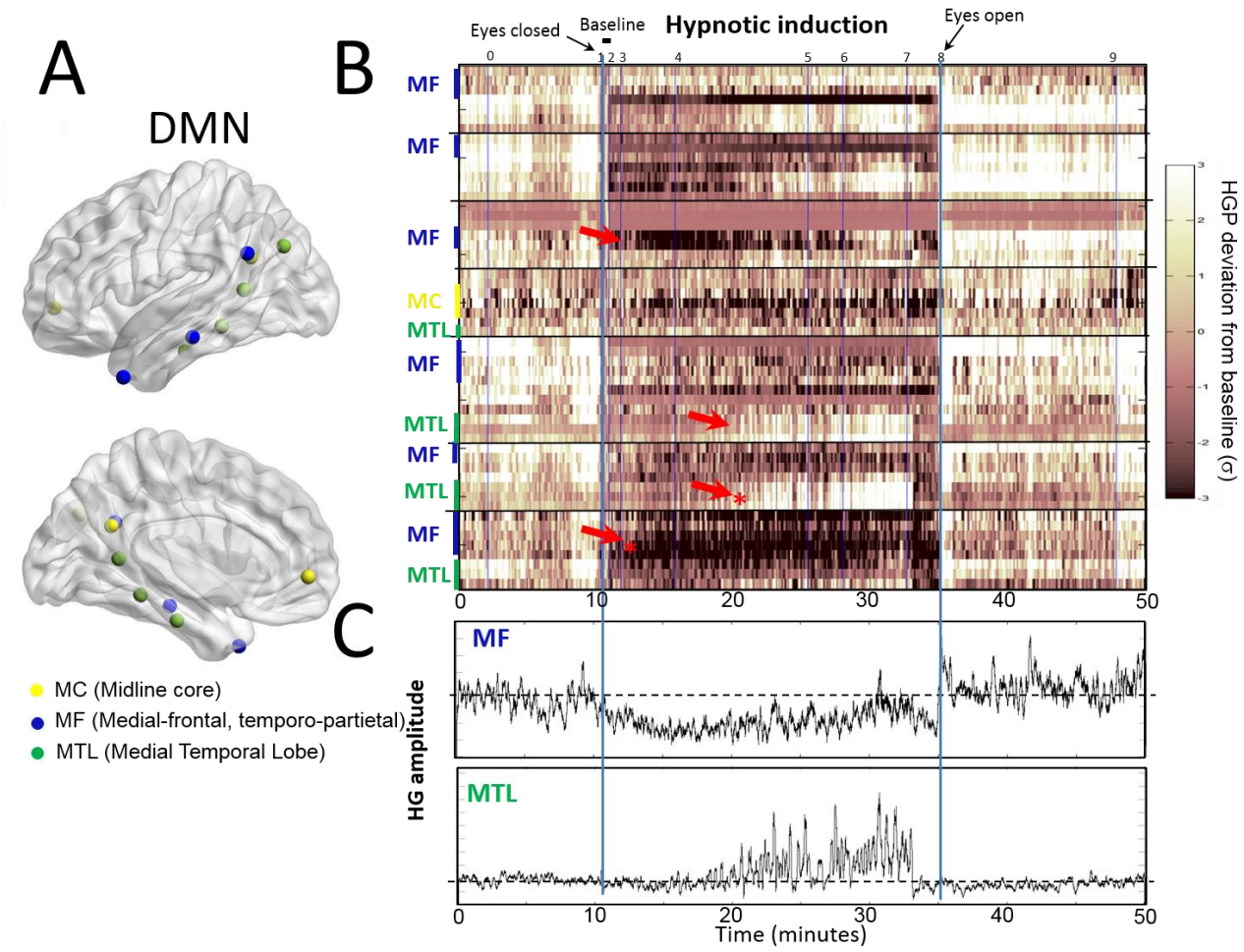

Figure 1: Activation and Deactivation in the DMN. A. Anatomical position of three subsystems of the DMN as described in [8], referring to the midline core (yellow), dorsal medial frontal/temporo-parietal (blue) and the medial temporal (green) clusters. B. Representation of changes in HGP across the hypnotic induction. Note the increase in the MTL and the simultaneous decrease in the MF subsystems (red arrows). C. Two examples of electrodes in the MF and the MTL displaying HGP decrease and increase, respectively. Electrodes correspond to positions marked with * in B.

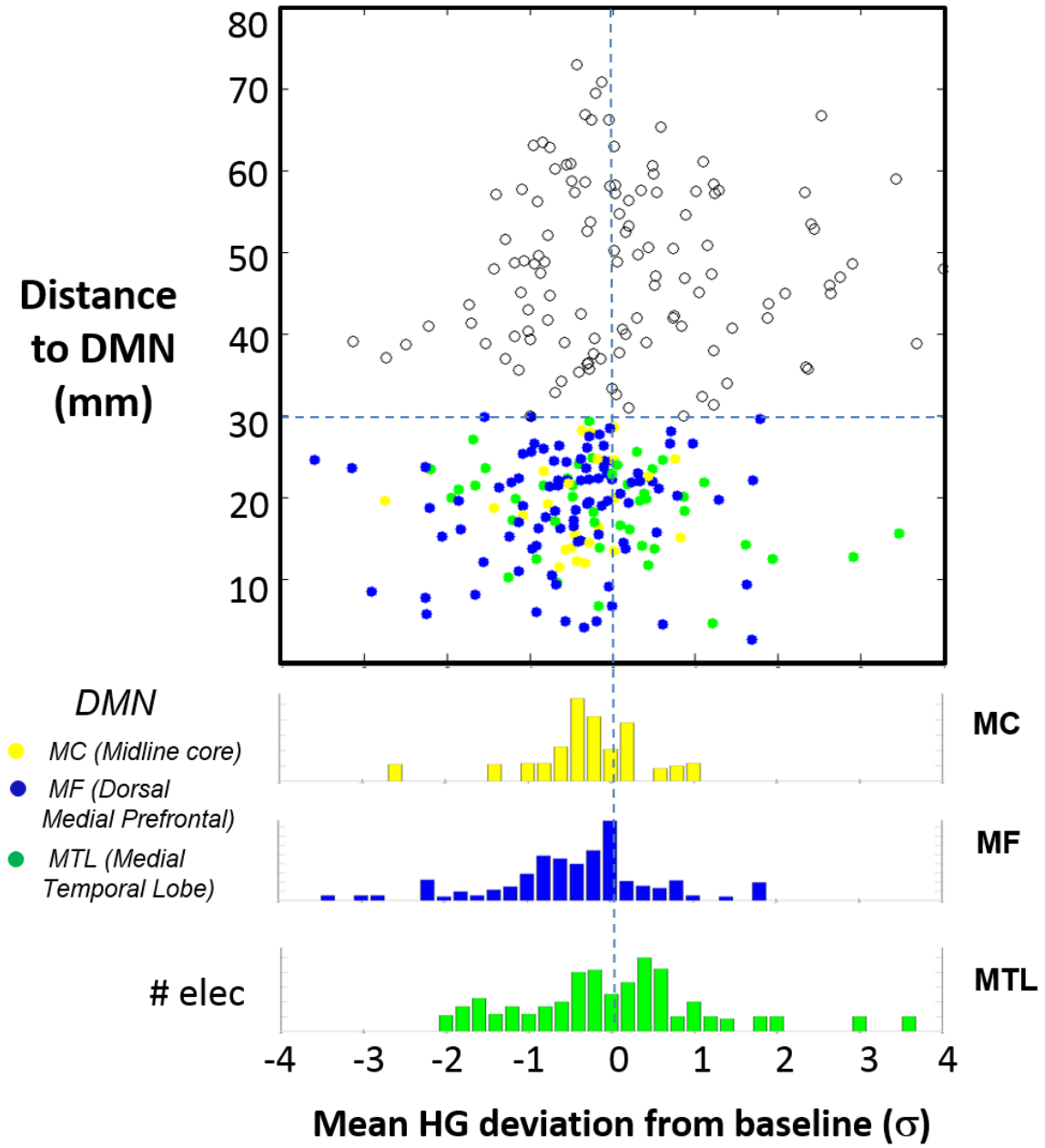

Figure 2: HGP as a function of distance from the DMN. Scatter plot in the upper panel represents HG values as a function of distance to the closest DMN hub, with different colors used for different DMN subsystems. The three lower panels show histogram of this relationship for each subsystem. Note the leftward shift of the MF and MC systems, indicating deactivation.

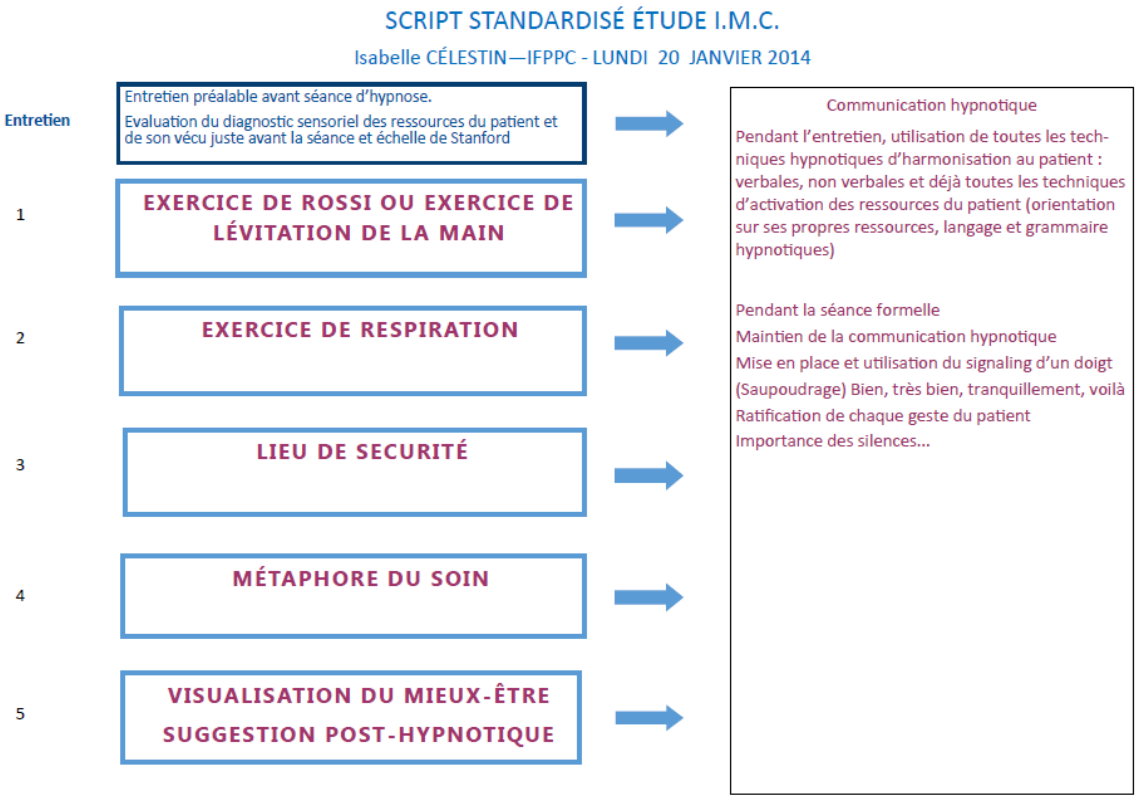

Figure 3: Standardized script of hypnotic induction. Five different stages were used to increase the depth of hypnotic trance.