

Exploring the neural correlates of spontaneity

Lucas Jeay-Bizot, Amy Whitmarsh, Uri Maoz, Aaron Schurger

Motor related cortical potentials (MRCP) in spontaneous actions, such as the readiness potential (RP), have been a key signal of interest in electro-encephalographic (EEG) volition research and the free-will debate. These MRCPs typically precede spontaneous movement onset by one second or more. In the case of the RP, the signal onset can be much earlier than the participants' reported time of conscious awareness of their decision to move, even when participants are instructed to be as spontaneous as possible. This has led many to claim that consciousness has no causal role in spontaneous actions. But it also suggests that, while spontaneous decisions might feel unprompted and abrupt, they may not be so at the neural level. The goal of our study was to empirically test the extent to which spontaneous movements were spontaneous at the neural level.

We therefore asked a group of participants to press a left or right button and another group to press or not press a button at a pre-ordained time while we recorded EEG, which allowed us to probe both decisions about *what* to do and *whether* to do it, respectively. To address the spontaneity factor, each participant performed these motor decisions under three conditions, (1) instructed (the outcome was dictated by the pre-cue); (2) preplanned (participant decided in advance); and (3) spontaneous (participant waited until the last possible moment to decide). In both groups, spontaneous MRCPs had onsets 1s or more prior to their button presses—indicating that spontaneous decisions are preceded by preparatory activity. So, we further investigated how much information about the upcoming decision existed in the brain before movement onset, using a machine-learning-based analysis (support vector machine).

We found that spontaneous *what* decisions were not predictable with above chance accuracy up until very close to movement onset, whereas *whether* decisions could be predicted earlier (~200ms for instructed and ~500ms for spontaneous). Preplanned decisions in both groups could be predicted early (~600ms).

These preliminary results suggest two main inferences. First, spontaneous *what* and *whether* decisions have distinct neural activity preceding them and may therefore be distinct neural phenomena. Second, assuming that the MRCPs convey no additional neural information on top of that available to the EEG decoder, the much earlier onsets of MRCPs relative to the onset of predictive information for spontaneous *what* decisions suggests that the early MRCPs at best contain non-specific information about the movement, perhaps reflecting a general increased readiness to move.