Dissociating dynamic probability and predictability in observed actions – an fMRI study

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Abstract

The present fMRI study investigated whether human observers spontaneously exploit the statistical structure underlying continuous action sequences. In particular, we tested whether two different statistical properties can be distinguished with regard to their neural correlates: an action step’s predictability and its probability. To assess these properties we used measures from information theory. Predictability of action steps was operationalized by its inverse, conditional entropy, which combines the number of possible action steps with their respective probabilities. Probability of action steps was assessed using conditional surprisal, which increases with decreasing probability.

Participants were trained in an action observation paradigm with video clips showing sequences of 9 to 33 seconds length with varying numbers of action steps that were statistically structured according to a Markov chain. Behavioral tests revealed that participants implicitly learned this statistical structure, showing that humans are sensitive towards these probabilistic regularities. Surprisal (lower probability) enhanced the BOLD signal in the anterior intraparietal sulcus. In contrast, high conditional entropy, i.e. low predictability, was correlated with higher activity in dorsomedial prefrontal cortex, orbitofrontal gyrus, and posterior intraparietal sulcus. Furthermore, we found a correlation between the anterior hippocampus’ response to conditional entropy with the extent of learning, such that the more participants had learnt the structure, the greater the magnitude of hippocampus activation in response to conditional entropy.

Findings show that two aspects of predictions can be dissociated: an action’s predictability is reflected in a top-down modulation of attentional focus, evident in increased fronto-parietal activation. In contrast, an action’s probability depends on the identity of the stimulus itself, resulting in bottom-up driven processing costs in the parietal cortex.