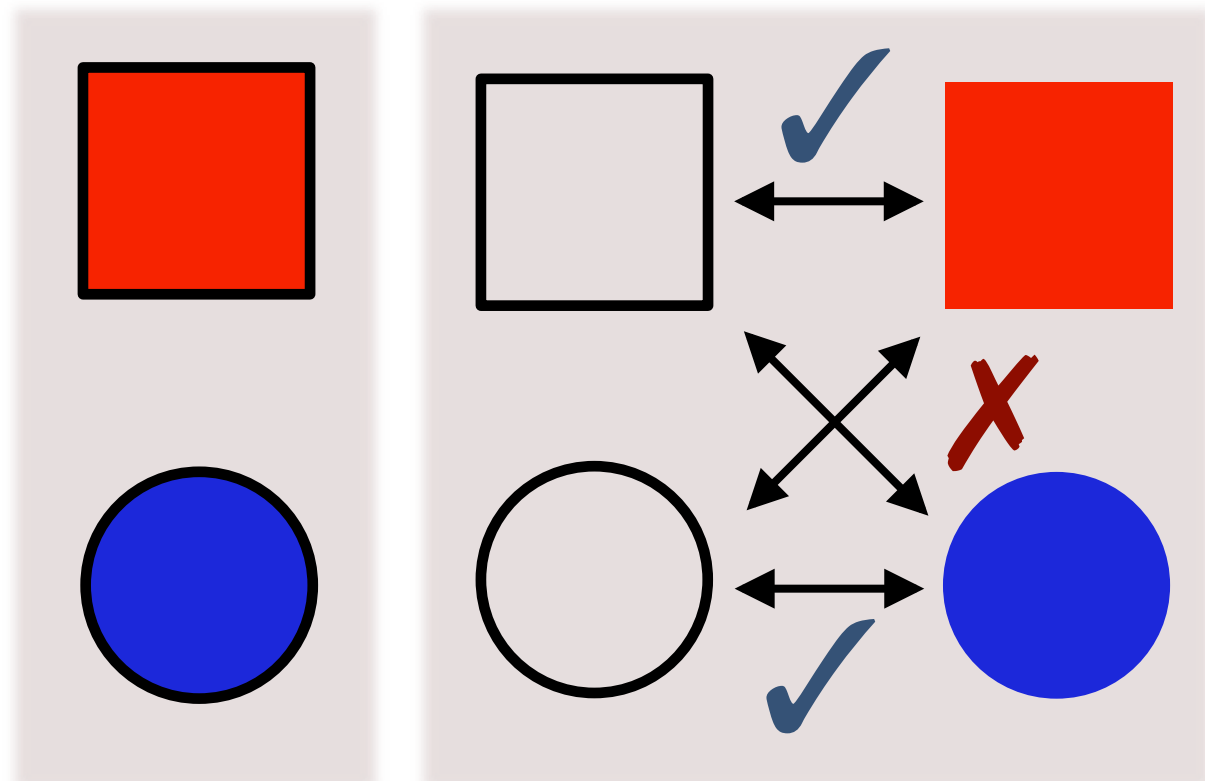


# The Binding Problem

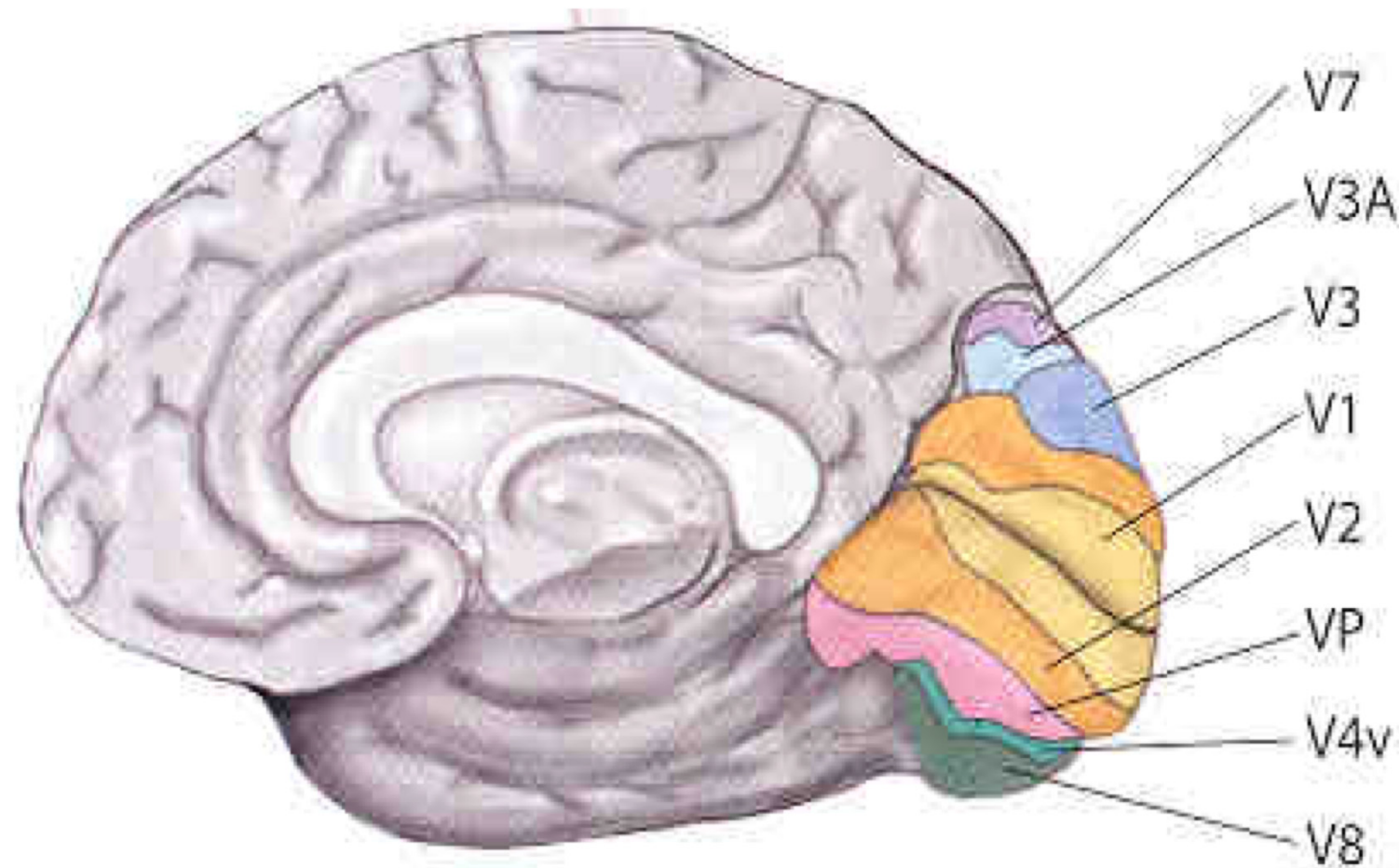
The binding problem refers to how the brain pre-consciously combines visual features, like colour and shape in the example below, to create coherent mental equivalents.



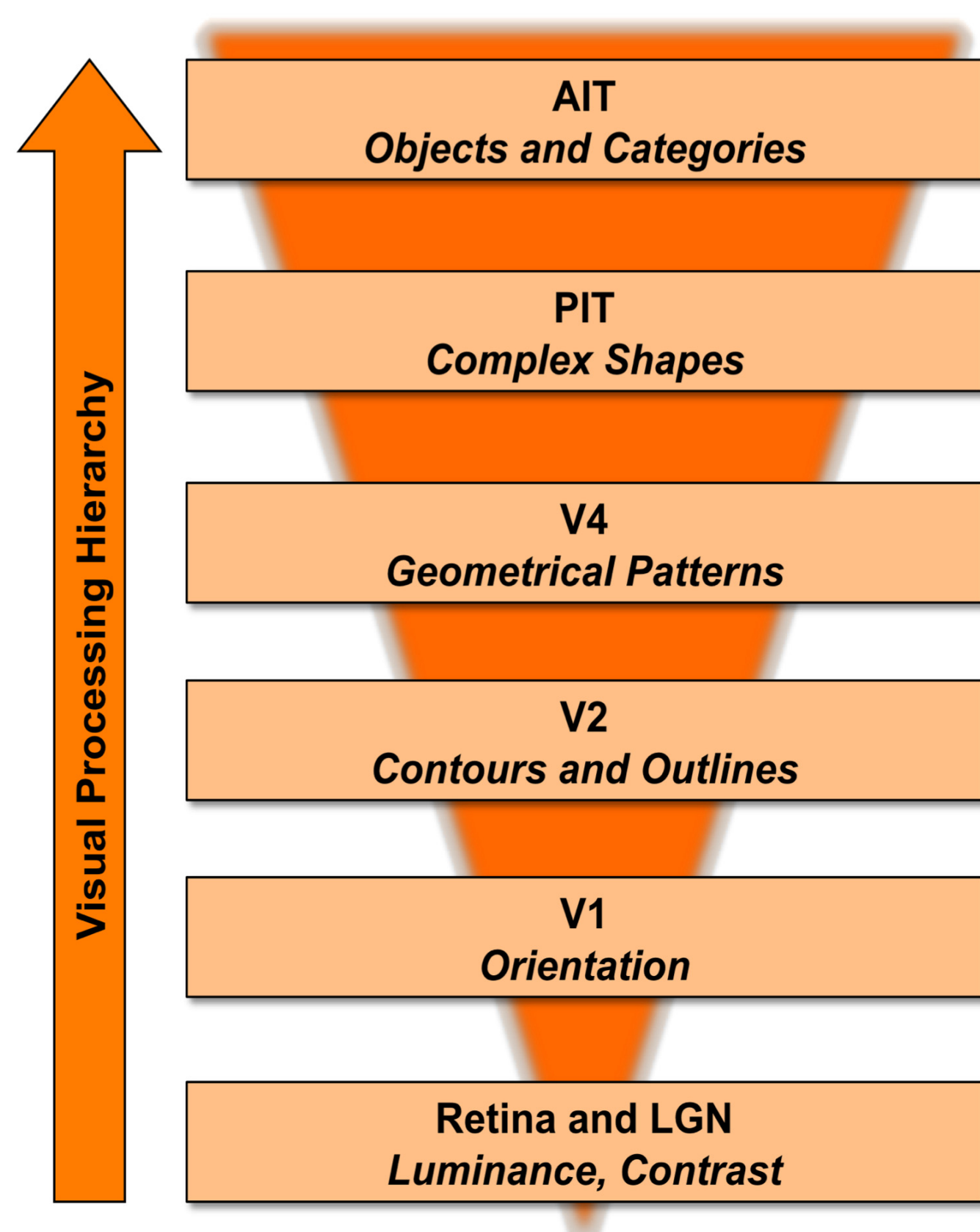
In the example above, when presented with a red square and a blue circle, how does the brain associate redness with squareness and blueness with circleness?

## The Visual System

To solve the binding problem, the brain must combine visual features processed in disparate brain regions (see below) by a hierarchy of processing layers.



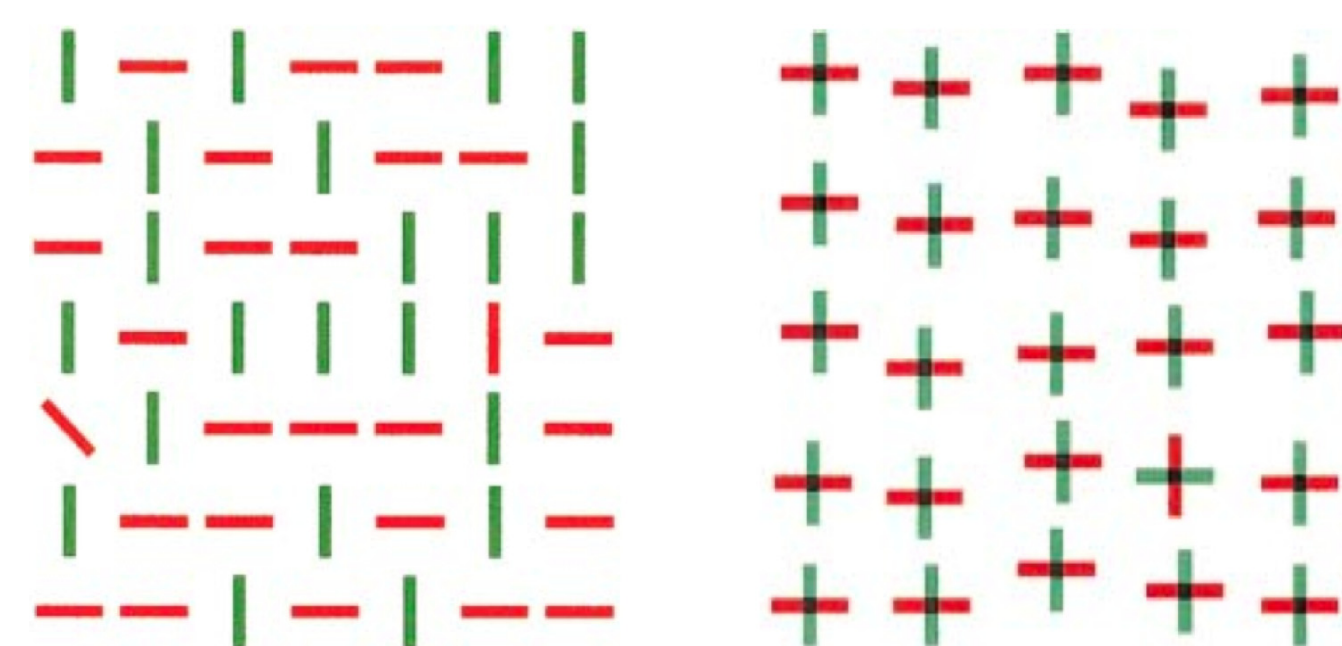
As in the figure below, lower layers in the hierarchy are organized as spatial maps of visual features like colour and orientation. Upper layers represent progressively more complex objects and structures.



## The Attentional Spotlight

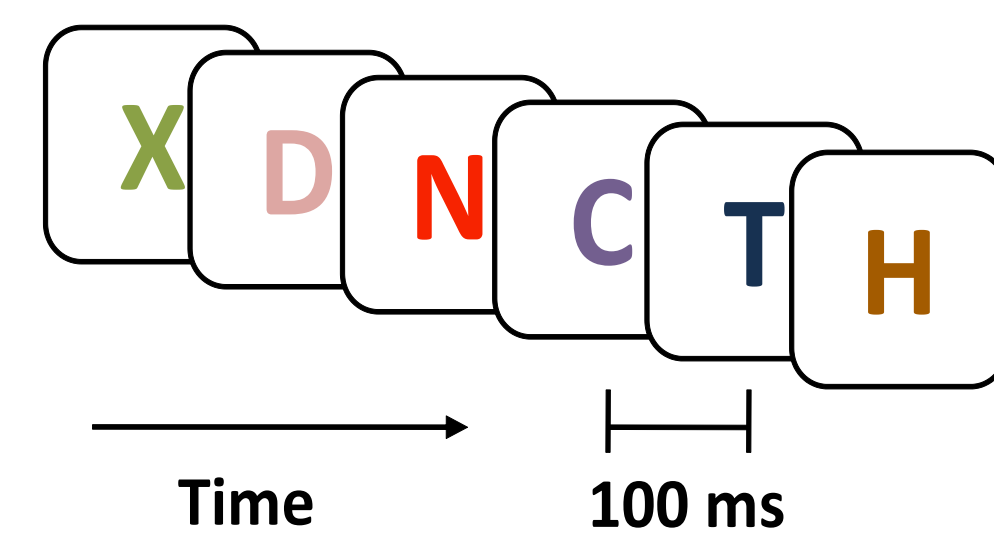
It is our ability to selectively focus spatial attention that allows us to bind features together into well-defined mental representations. This role of the *attentional spotlight* becomes evident in visual search experiments.

Finding a oddly oriented bar in the left array below is almost instantaneous and effortless, whereas finding a red vertical bar in the right array takes much more work. This is because attention is required to bind together spatial features only in the latter case.

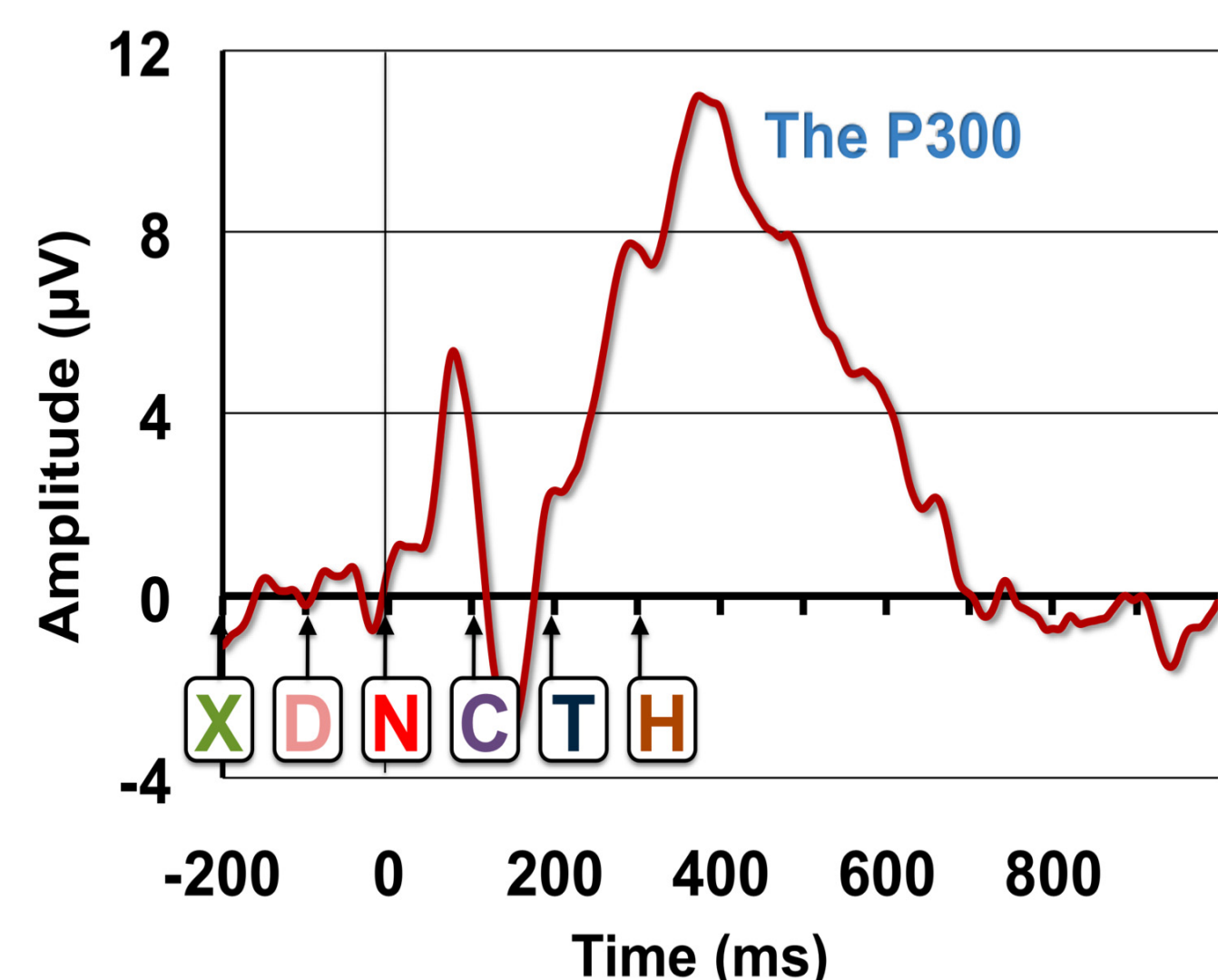


After Wolfe et al. (1999)

We study how attention is deployed in time to correctly bind fleeting stimuli, using rapidly presented streams of stimuli like in the example below. Here, when asked to identify the red target letter (N), people often make errors and report letters around the target. Analyzing the pattern of these errors tells us something about the temporal role of attention in feature binding.



We directly observe binding in action by recording EEG, also called *brain waves*. These electrical signals contain systematic fluctuations reflecting neural processes. For example, the **P300** in the figure below is evoked by the binding of the target **N**. Analysis of EEG data allows us to investigate how the brain solves the binding problem.



Binding is a problem for the brain despite its seemingly effortless resolution in daily life. Understanding how the brain solves it gives us insights into the neural correlates of consciousness.