

The Neural Substrates of Non-Conscious Working Memory

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Abstract

Background: Despite our distinct impression to the contrary, we are only conscious of a fraction of all the neural activity underlying our thoughts and behavior. Most neural processes occur non-consciously, and in parallel with our conscious experience. It is, however, still unclear what the limits of non-conscious processes are in terms of higher cognitive functions. Many recent studies have shown that increasingly more advanced functions can operate non-consciously, but non-conscious information is still thought to be fleeting and undetectable within 500 milliseconds. Here we used various techniques to render information non-conscious, together with functional magnetic resonance imaging (fMRI), to investigate if non-consciously presented information can be retained for several seconds, what the neural substrates of such retention are, and if it is consistent with working memory maintenance.

Results: In Study I we used an attentional blink paradigm to render stimuli (single letters) non-conscious, and a variable delay period (5 – 15 seconds). It was found that non-conscious memory performance was above chance after all delay periods, and showed no signs of decline over time. Univariate fMRI analysis showed that the durable retention was associated with sustained BOLD signal change in the prefrontal cortex and cerebellum during the delay period. In Study II we used continuous flash suppression (CFS) to render stimuli (faces and tools) non-conscious, and a variable delay period (5 or 15 seconds). The durable retention of up to 15 seconds was replicated, and it was found that stimuli identity and spatial position was retained until prospective use. In Study III we used CFS to render tools non-conscious, and a variable delay period (5 – 15 seconds). It was found that memory performance was not better than chance. However, by using multi-voxel pattern analysis it was nonetheless possible to detect the presence vs. absence of non-conscious stimuli in the frontal cortex, and their spatial position (left vs. right) in the occipital cortex during the delay period.

Conclusions: Overall these findings suggest that non-consciously presented information (identity and/or position) can be retained for several seconds, and that persistent neural activity in frontal and posterior cortices are the likely neural substrates of such retention. These findings are consistent with working memory maintenance of non-consciously presented information, and thereby add constraints to models of working memory and theories of consciousness.

Keywords

non-conscious, working memory, neural substrates, visual perception, consciousness, functional magnetic resonance imaging (fMRI)

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