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MY BRAIN, YOUR BRAIN, OUR BRAIN IS MORE THAN THE SUM OF ITS PARTS

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Memory is a crucial cognitive process that acquires the essential informations in the continuous stream of perceptual inputs in order to forge a consistent episodic and semantic memory for survival purposes. This high cognitive process has been proved to take place at early stages of life and even in utero. Even though memory is well investigated in the scientific research, essential questions remain unresolved. Indeed, the underlying neural processes of short and long-term memory are still debated among researchers and in particular the concrete role of hypothalamus in encoding and reactivation of memories. Indeed, this debate has split researchers into two different camps with two divergent hypotheses on the neural organization of memories.

Tallman et al. (2022) recently investigated in humans how neural activations and connectivity modify as the memories age across time. Subjects were asked to memorize scenes and complete memory recognition tasks while being analysed in a fMRI scanner. This study focused on longer time periods of memories going from one hour after testing to one month. Results showed that memory accuracy and other behavioural measures changed across time as expected but most importantly cortical networks activity showed a significant variation related to the memory age. In fact, more than 18 brain regions predominantly in the parietal lobe showed modified activity across the testing periods.

Most importantly, the activation between ventromedial prefrontal cortex and the posterior parietal cortex showed a significant increase with memory age suggesting that this pathway is crucial in long-term memories reactivation. In contrast, fMRI analysis showed a notable decrease in activity during retrieval of older memories in between the hippocampus and left parahippocampal

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cortex. These results support strongly the standard consolidation theory whom hypothesized that the hippocampus is mostly needed for newly encoded memories that through gradual strengthening of cortico-cortical connections consolidate and become independent of the hippocampal regions to be retrieved.

This model is also supported by the findings of Gilmore et al. (2021) study on episodic memories retrieval in fMRI analysis. The authors compared recent and old episodic memories and measures their retrieval score in addition to brain imagery investigation of hippocampus and neocortex regions activation. The results revealed a gradual time-limited of hippocampus in autobiographic memories recall. Although the authors observed hippocampal activity during older memories retrieval notably in the posterior regions, this activity was not significantly different from baseline patterns. However, significantly different activity between old and recent reminiscences was observed across the whole brain, including strong hippocampal divergent activity. However, these findings are not consensual within the neuroscientific community because opposite results were also found.

In fact, a current study has been conducted by Roy et al. (2022) using tissue phenotyping in mice to test engrams activation with memory age. They first found significant activation in the limbic system and surrounding areas that have already been proven to play a crucial role in learning and encoding new informations, particularly emotional inputs. However, using optogenetically stimulation, they observed robust memory recall in multiple engram ensembles and especially in hippocampal CA1 (4Hz stimulation only) suggesting that fear memories retrieval is hippocampal-dependent. Chemogenetic stimulation revealed that memory recall level was significantly better when multiple engrams were activated contrary to single engrams stimulation. Indeed, these results indicate how functional engrams in charge of a specific memory recall are scattered in multiple brain regions and how crucial it is for these connected ensembles to be activated together in order to achieve pre-eminent retrieval. Moreover, these findings support the unified engram complex hypothesis theory and demonstrate that long-term memories recall is hippocampus-dependent.

This theory is also supported by the findings of Bartsch et al. (2011) who evaluated the impact of CA1 hippocampal neurons dysfunction on in episodic memories retrieval. Chosen subjects were rare patients with a rare acute transient global amnesia (TGA) that focally damages hippocampal CA1 neurons which hypothetically play a crucial role in episodic memory. Autobiographical memory scores were evaluated in control and condition groups and compared in categorical age-dependent distribution. Behavioural and imagery results revealed an important

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impairment in TGA subjects. However, the authors observed that the impairment was temporally graded, showing a significantly higher retrieval score in older memories congruent with the standard consolidation model as well as the multiple trace theory. Indeed, these results support gradual hippocampal-independency of memories with age but also the necessity of hippocampal CA1 neurons integrity in order to retrieve autobiographical memories. Yet, a total hippocampal-independency to recall episodic reminiscences is not supported by these findings.

We clearly can observe that neural organization of memory processes remain unclear because of the multiple divergent findings among neuroscientists. Actual findings divide the scientific community in two distinct ideological theories on the underlying mechanisms of long-term memories consolidation: standard consolidation model and multiple trace theory. However, neuroscientists agree on how learning and memory crucially impact our cognition and behaviour and how our brain substantially functions as an interconnected network. Moreover, cultural, and collective knowledge also have an important impact on individuals' reflexions and actions. Humans are social primates that essentially live in societies based on cooperation and communicating collective knowledge and beliefs in order to increase survival chances. Investigation of large networks influence on individuals thinking and behaving is poorly explored in the scientific domain although collective mind theory and shared underlying neural mechanisms questions remain unresolved.

A recent review published by Momennejad (2021) investigated these questions by exploring typologies dynamical influence on collective behaviour. Indeed, via a laboratory-based experiment searchers formed multiple clustered and non-clustered typologies that could have conversational exchange before and after a recall test. Results revealed that mnemonic convergence was significantly higher in non-clustered groups meaning that collective memory were more aligned in the condition where separation degrees are smaller. Mnemonic similarity not only can be predicted by the type of topology but also by the type of relationship between the individuals and the temporal order of shared informations. Similar results have been found also with collective beliefs by using the same experimental methodology scientists found a significant shaping and synchronisation of beliefs even in individuals who never directly communicated. These results reveal how topologies communication highly impact our beliefs and how fast false informations can spread.

Impact of topologies on collective intelligence also have been investigated by measuring problem-solving and invention in two types of networks: full connectivity and partial connectivity. Results demonstrated that

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partial connectivity topologies achieved higher levels of problem-solving measures than full connectivity groups. This distinct divergence of findings indicates different kind of typologies have contrasted functions in society. In fact, collective knowledge and culture need a more communicative topology to achieve best spread of informations, on the other hand cumulative cultural achievements are reached by more partial connectivity.

Although these results demonstrated that topologies have a crucial impact on cognition and behaviour, scientist revealed that networks also shape brain activity and neural response patterns. Indeed, the authors used cerebral functional imagery and displayed pictures of individuals with various degree of separation with the subjects who were mainly bridge ties between other members. In the absence of any expressed instructions, a common neural pattern fired congruently with the individual position in the social network meaning that relationships within topologies have their own neural activation. Moreover, another study demonstrated that neural responses were more similar between subjects within a topology and that the closer the relationship was the higher their neural activity correlated.

A similar recent study conducted by Hyon et al. (2020) supports these results. In fact, the authors investigated brain connectivity with fMRI analysis of residents of a village and hypothesized they would have similar neural activity and connectivity. Their results confirmed their hypothesis and mainly showed that a machine-learning algorithm could significantly predict the social proximity between subjects based only on their baseline brain activity. Personality component and demographic variables were also controlled in order to confirm that this prediction has no moderators. These findings really demonstrate how social topologies can shape functional neural connectomes.

In summary, cognitive neural pathways responsible for episodic memories retrieval remain unclear and is still a debated topic among neuroscientists. Both theories, standard memory consolidation model and unified engram complex theory have been demonstrated by searchers in various behavioural and physiological methodologies but their validity cannot be disentangled from each other. However, learning and memory effect in shaping collective minds has been strongly demonstrated not only in behavioural and cognitive processes but also in neurobiological activity. Further studies should deepen these findings in order to assess the function and the steps in the cognitive and neurobiological conformity.

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