RSC

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1 Connection

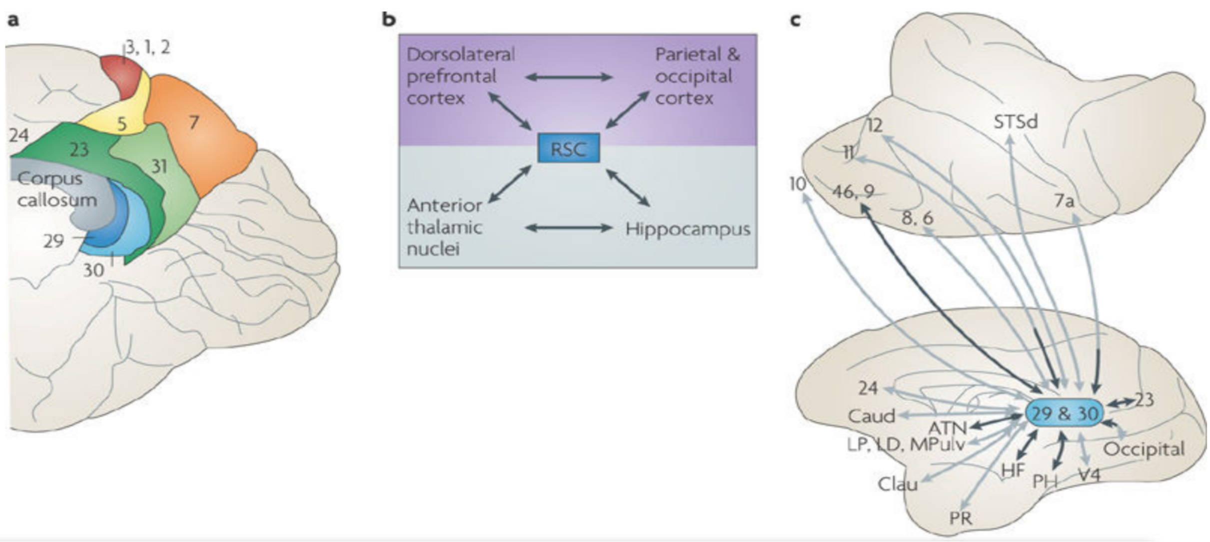

Figure 1: "Location and principal connections of the retrosplenial cortex (RSC). a. Medial surface of a human brain showing the position of the RSC (Brodmann's areas 29 and 30) (blue) and the remaining posterior cingulate cortex (areas 23 and 31) (green). b. How the RSC can help to integrate information in cortical sensory and prefrontal sites (upper half of the schematic) with subcortical sites required for memory (lower half). c. Principal connections of the macaque (Macaca fascicularis) RSC. The darker arrows indicate denser projections (bicoloured arrows indicate denser projections in the direction indicated by the darker colour).All numbers refer to Brodmann's area designations. AD, anterior dorsal thalamic nucleus; AM, anterior medial thalamic nucleus; AV, anterior ventral thalamic nucleus; Caud, caudate nucleus; Clau, claustrum; HF, hippocampal formation; LD, laterodorsal thalamic nucleus; LP, lateroposterior thalamic nucleus; MPulv, medial pulvinar; ParaS, parasubiculum; PH, parahippocampal cortex; Post, postsubiculum; PR, perirhinal cortex; PreS, presubiculum; STSd, dorsal superior temporal sulcus; Sub, subiculum; V4, visual area 4".[18]

Note: The rat RSC is different from the primate RSC. The rat one does not have the conterparts to areas 23 and 31 as in primate's one; also, the rat RSC is bigger in proportional sizes - it covers more than half the cerebrum length. In this note, we uses the terms of granular a/b (Rga/b) and dysgranular (Rdg) to be consistent with most of the studies in areas 29 and 30.

1.1 Input

- Reciprocal connections with multiple regions regarding spatial representation: the hippocampal formation and subiculum, pre/para subiculum, the parahippocampal region (e.g. the entorhinal cortex) and some thalamic nuclei, PPC, anterior cingulate.[18, 2]
- Reciprocal connections to prefrontal cortex, "which provide an indirect route" for hippocampal influences "on the dorsolateral prefrontal cortex and vice versa" [18].
- Reciprocal connections with area V2, V4 (visual information), cingulate areas 23/24t and the dorsal superior temporal sulcus [18].

Note: RSC receives sensory information that are not highly processed, e.g, the visual input from V2 & V4 region and the sensory input from PPC, then passes these information onto the hippocampus and anterior thalamic nuclei (which has reciprocal connection to the cerebral cortex).

1.2 Output

See the reciprocal connections mentioned above 1.1.

1.3 Main Components

- granular regions (area 29): has more reciprocal connections to the thalamic nuclei and postsubiculum with head-direction representations [18]. For internally guided navigation, this region is more important comparing to the dysgranular cortex [13].
- dysgranular cortex (area 30): has more reciprocal connections with visual areas [18] It is more important for visual directed navigation[13].

2 Function

- Simultaneously Process Multiple Stimuli: Lesions on RSC disrupted performance on different tasks requiring processing multiple sensory input simultaneously, e.g, objects, space, goals, and fear [10, 8, 11].
- Head Direction (HD) Cells: around 10% of RSC cells are HD cells. [6]. Most of them are not behaviourally modulated (e.g. velocity of locomotion) [5]. Although RSC has reciprocal connections to the postsubiculum, the thalamic nuclei and entorhinal cortex, the RSC is not believed to be important for the head-direction signal generation in those regions [17].
- Locomotion encoding: some cells robustly map the locomotor behaviors (e.g. angular and linear velocity, turnings) irrespective of location [2, 6, 14]
- Route and sub-route cells: they are different from the route cells in PPC. The RSC route cells are very sensitive to route position relative to the broader environment (e.g. boundaries conditions), whereas the PPC ones are not. Also, the route cells in the retrosplenial cortex can register at different scales and have periodic activation patterns when a segment repeats in the route as shown in Figure 2. [2, 3]
- Simultaneously encoding allocentric, route-centric and egocentric information or two of them: For example, those ones that encoding both the egocentric and route centric frames exhibited firing patterns for either left or right turns at different positions in one route, e.g, the cell only fire when the rat is turning left in the W maze but not the M maze. And as an example of encoding both the allocentric and route centric frames: some cells fire differently if the track is relocated to different points in the room, and one can determine the rat position in the room from it. Sometimes, RSC cells register egocentic turning behavior, allocentric heading direction, and the route information at the same time. It is thought to be, "in principle, capable of directing remapping in the grid and/or place cell networks and, perhaps, defining the conditions under which resets occur".[2].
- Episodic Memory Encoding: the RSC is shown to be one of the brain regions has intense firing when retrieving autobiographical memory [15]. Patients with damage in RSC can not understand novel information given either by verbal or visual, and have difficulties recalling recent but not very old autobiographical events [18].
- Short-term 'buffer' for updating representations of different reference frame. It is reported that "activity in the RSC increased specifically when topographical representations needed to be updated, integrated or manipulated for route planning, or when new topographical information was acquired".[1]

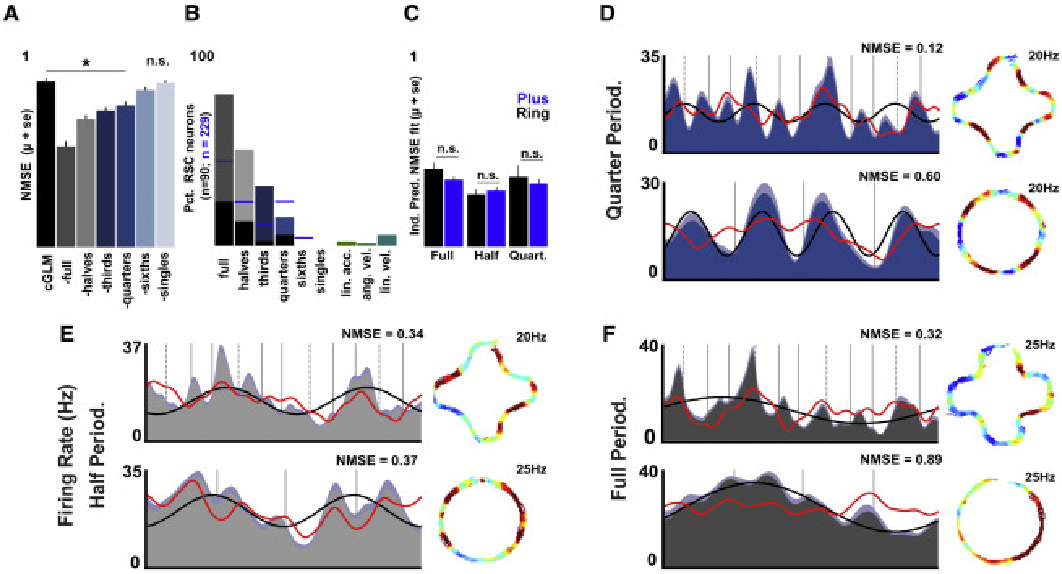

Figure 2: "RSC Neurons Exhibit Spatially Periodic Activation Patterns on a Plus Maze and a Ring-Shaped Track (A) The amount of cells repeat at different periodic activation patterns. (B) Shown here is the percentage of RSC neurons significantly impacted by each spatial fragmentation or egocentric-based movement variable on the ring track. Black bars show the percentage of all neurons recorded on the ring and plus (n = 78) that were significantly modulated by the same spatial predictor for both tracks. Blue lines show the percentage of RSC neurons recorded during plus track running that were significantly modulated by each spatial predictor (same as bars in Figure 2F). (C) Mean (SEM) of fit to individual predictors for all neurons that exhibited significant modulation by full, halve, or quarter spatial predictors in either track running condition (blue, plus; black, ring). Fit was not statistically different between track types, indicating that the spatial periodicity was equally strong across conditions. (DF) Mean activation profiles for single RSC neurons that exhibited significant modulation at the quarter scale (D), half scale (E), and full scale (F) during ring traversals (bottom, ring; top, plus). Right: corresponding 2D rate maps".[3]

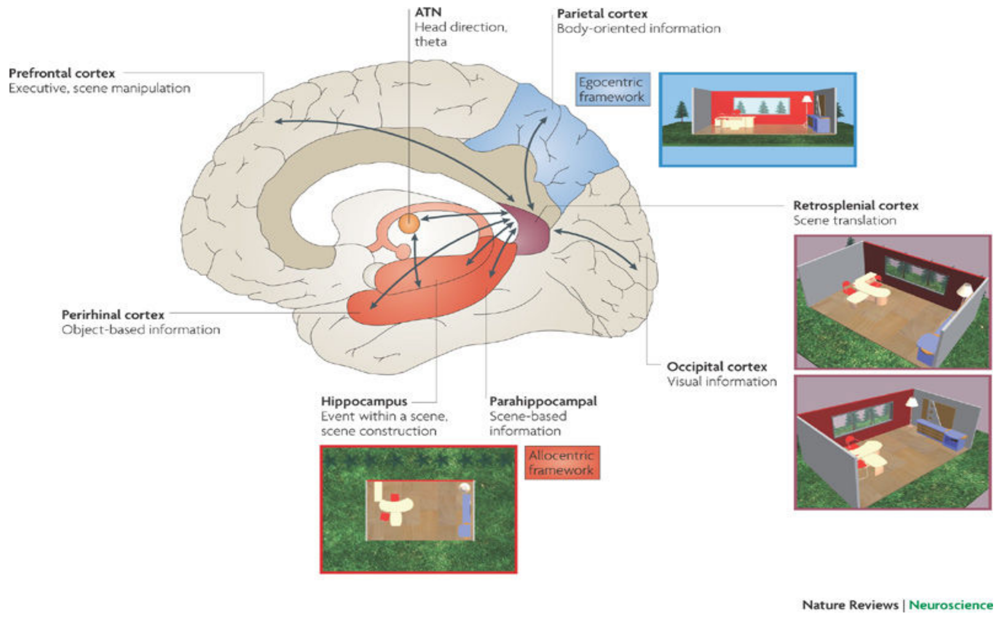

Figure 3: "Effective episodic memory, navigation and future thinking all require the ability to integrate and manipulate different frameworks of information, for example egocentric (self-centred) and allocentric (world-centred) frameworks. By virtue of its principal connections, the retrosplenial cortex is uniquely placed to enable translation within these domains. ATN, anterior thalamic nuclei".[18]

2.1 Scales

- Spatial Scales: Retrosplenial cortex registers sub-routes in complex trajectories - periodic firing activities at multiple spatial scales. It also provides information for the distance within the trajectories. [3]
- Temporal Scales: The theta rhythm is locally generated in RSC. Also, it mediates some aspects of hippocampal theta rhythm.[16]

2.2 Evidence of Building Blocks / Modularization

- The information in different frames are registered simultaneously and can be reused when part of the circumstances changes.
- The sub-routes encoding.

2.3 Evidence of Lateralization

"Verbal and visual memory deficits are often, but not always, consistent with the side of the lesion". The spatial impairment in patients with unilateral RSC leisions, can recover after several months, and it is suggested that this the remaining RSC part supported this recovery.[18]

2.4 Empirical Lesion studies

- rats or humand with RSC lesion have difficulties in processing distal land marks and plan routes among them [2, 12]
- RSC-lesioned rats showed more errors of failing to visit an arm of the maze in an experiment, but no impacts on errors of revisiting an arm in the same experiment. When the delay time increased from 5s to 30s between training and testing, the RSC-lesioned rats were impaired and committed more errors of revisiting an arm.[9]

For more lesion studies, please refer to the session *Different types of RSC lesion-induced impairments* in [18].

3 Computational Model

- RSC is been proposed to transform allocentric and egocentric representations. "In other words, the RSC helps to switch between egocentric, viewpoint-dependent (mediated by the posterior parietal cortex) and allocentric, viewpoint-independent (mediated by the medial temporal lobe) frames of reference in relating egocentrically based views of the world to the allocentric positions and head orientations with which they are associated" [4].

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