

Persistent versus fading memory in serial recall: an analysis through recurrent neural networks

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Memory is a fundamental cognitive process involved in many everyday activities, such as learning new information, retaining past experiences, and solving problems. However, memory is not a unitary function: it encompasses a variety of processes and mechanisms that may be differentially engaged depending on the task and temporal demands. Among these mechanisms, two broad forms can be distinguished: persistent memory, which supports the long-term maintenance of information, and fading memory, in which information is maintained only transiently.

In psychology, serial recall is an experimental task requiring the recall of items in their original order, which is extensively studied to investigate the mechanisms of working memory. For this reason, a wide range of models has been developed to account for experimentally observed results. While most models rely on separate representations of item and order, Botvinick and Plaut (2006), motivated by new electrophysiological data from monkeys, proposed a dynamical model based on recurrent neural networks that employs a unified representation of item and order with a very simple cell dynamic [1].

Over recent years, recurrent neural networks have become increasingly prominent and effective through the introduction of new mechanisms and cell dynamics that enable more complex network behavior. In particular, fading memory can now be implemented using gated recurrent unit (GRU) cells [2], while persistent memory can be achieved with bistable recurrent cells (BRCs) [3], which rely on bistability.

In this work, we investigate which type of memory is better suited to represent this task of serial recall. While both fading and persistent memory can reproduce the main experimental findings, certain experiments show that bistable recurrent cells better replicate the observed experimental results and vice-versa. By combining both types of cells within the same network and modulating their relative proportions, we aim to better understand the respective roles of these memory mechanisms and their impact on experimental replication (Figure 1). In addition, we perform internal network analyses to examine how bistability is exploited during task execution. Finally, we apply lesions to the network, revealing that lesions affecting persistent memory lead to different outcomes than lesions affecting fading memory.

References

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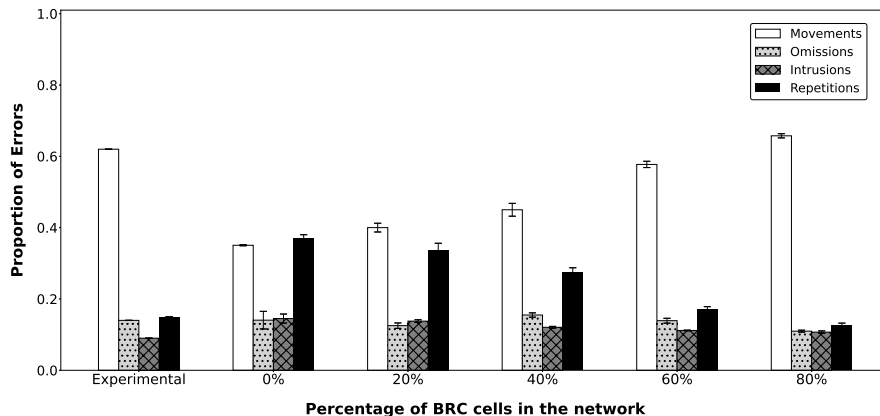


Figure 1: Proportion of errors for networks with varying BRC cell ratios. Errors include movements (item in the wrong position), omissions (item not recalled), intrusions (item not in the sequence), and repetitions (same item recalled multiple times).