Anne Koutures
Department of Neuroscience, Boston University
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Dr. Joseph McGuire
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A Commentary on Cognitive Boundaries for Episodic Memory Structure

Upon entering an elementary school classroom or my college level Sensory Neurobiology class, you may find it odd that at both levels the same topic is being discussed: the five senses. Why are the human senses integrated so heavily into the U.S education system? Senses are how we experience external reality. What humans see, hear, taste, smell, and feel is what our brain perceives as real, but what does each second of perceived reality become the instant our senses are no longer stimulated? What is the basis of an individual's idea of their lived reality? Memories. The working memory specifically is where every sensational experience is first processed, determining the ease at which its memory can be retrieved. How the working memory decides which information to make accessible is a question research has sought to answer for years.

Nature Neuroscience published a study by Zheng and colleagues aiming to answer questions about the neural components involved in working memory processing. The study consisted of 20 subjects, recorded on a cellular level in the medial temporal lobe (MTL), specifically the memory related structures, the amygdala, hippocampus, and parahippocampal gyrus.

While recorded, the subjects participated in a task consisting of three parts: an encoding phase, scene recognition phase, and temporal discrimination phase. During encoding, 90 clips never seen before by the subject were shown. The series of clips consisted of hard boundaries, the transition from one clip to a brand new one, soft boundaries, the transition between different scenes of the same clip, and no boundaries, an image with only one shot. After watching the clips, the scene recognition phase required participants to identify a presented frame as old or new, in regard to the clips. The following temporal discrimination phase presented two related images from a clip, and subjects identified which occurred first in time. Recordings gathered data about neural activation states and firing rates and patterns of cells.

The results of the study identified two types of cells active in the brain during working memory processing: boundary cells and event cells.

Boundary cells spiked just after the presentation of soft and hard borders. Correctly recalled frames in the scene recognition task were marked by stronger boundary cell responses during the initial encoding of the stimulus.

Event cells differed from boundary cells in that they consistently fired only after presentation of a hard border. In other words, event cells showed consistent firing when the transition between clips linked two unrelated pieces of content. The observation indicates that the organization of memory may differ based on the ability of a stimulus to be contextually related to previous encodings.

The discovery of boundary and event cells in response to different transitions in content was extended to the general processes of encoding and recall. Zheng's study found that the neural activity during encoding reinstated itself during both correct and incorrect identification of images as “seen before”. This conservation of the reinstatement process is applicable to research on false memories, illusions, etc., as correct and incorrect recall of events are essentially indistinguishable.

Zheng and his colleagues make the most of their data by analyzing multiple possible conclusions and confounds. Analysis was extended to cell firing rates and their relationship to theta waves. The interest in the theta component came from a previous study by Rutishauser et al. (2010), linking theta activity to memory consolidation and plasticity. Event cell activity was found phase-locked with theta band signals after both soft and hard boundaries when the temporal order task was done successfully. In other words, phase-locking of event cell signals to theta signals may be the event responsible for temporal memory. The consideration and application of background research in the study explicitly highlights the former knowledge the team sought to expand on. Building upon old knowledge furthers the depth of information gathered in a specific area of research, inching this area closer to breakthrough discoveries.

Evidencing the importance of new research expanding on old, Lee and Chen (2022) conducted an fMRI study finding that different posterior medial cortex (PMC) activation patterns exist for the same difference in boundaries studied by Zheng. While the activity of the brain during transitions within the same movie (or Zheng's soft boundary) was found significantly similar, the opposite was observed for the transitions between different movies (or Zheng's hard boundary). The authors of the fMRI study propose that encoding of clips from the same movie recruits brain activity specific to relating the context between clips, resulting in a smoother transition between activity states, as they remain similar. Secondly, they propose that encoding unrelated clips requires a full shift change in neural activity, likely a result of the brain having to recognize a new, non contextualized stimulus. In turn, Zheng's work proved beneficial in advancing research on the different brain networks involved in processing related and unrelated events.

Discussed in the paper are many areas of possible concern regarding the visual aspect of the study playing a role in its findings. The team modified their study in order to account for possible visual confounds, notably finding that boundary and event cells did not fire at the onset and offset of clips, also a visual change. Is it however possible that it is due to the onset and offset of clips transitioning from visually complex scenes to blank scenes that the cells do not fire? Incorporating a different sensory stimulus such as sound or touch and comparing the results to the visual study would not only confirm the existence of these memory cells, but also drastically improve the credibility of the study.

Zheng's discovery of boundary and event cells serves as an impressive pathway to a deeper understanding of human memory. One thing I would have liked to see that could be done in future studies is an EEG recording during both the correct and incorrect identification of an image as "seen before". An EEG allows for observation of the ERN component, an error induced negative signal in the brain. If no ERN exists upon false recall (before the subject is told it is false) then the brain may have no way of knowing that it made a mistake, making the false version of the individual's lived reality appear to be true. Further studies may also find significance in studying the quantifiable level of boundary cell responses, as there may exist a threshold value at which an encoded stimulus is made available for recall.

Works Cited

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