Narrative Memories Woven by an Intertextual Hippocampus

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Abstract: Narratives fundamentally shape the way we remember real-life experiences. However, neuroscientists have only begun to understand how narratives impact the way our brains support memory. In this opinion piece, I illustrate how the hippocampus, a key region of the brain for memory, transforms our experiences into larger narratives in memory. Furthermore, I argue that the hippocampus provides a biological basis for "intertextuality" – that is, all experiences or texts may be necessarily understood and remembered in relation to other experiences or texts. An intertextual hippocampus has tangible consequences for our lives and our art.

Keywords: narratives, memory, intertextuality, neuroscience, hippocampus

Introduction

Our memories often take the form of a larger story which can be elicited with a reminder. One personal reminder is a tapestry on my wall, an abstract geometric array woven from black and rust orange yarn. This is my grandmother's tapestry, "Walk of Fame," and its appearance readily conjures a series of interrelated scenes scattered throughout time. I remember curiously looking over the half-finished tapestry on my grandmother's room-sized loom. Seeing my interest, she later gave me my first lesson in weaving, showing me how to use a device called a shuttle to pull threads of yarn across the loom, and then to pull certain levers to intertwine those threads into a textile. I can then envision the room where the loom once stood, vacant except for a closet full of yarn, following her death; my spouse's aunt handing me a beautiful rust orange scarf, knitted from my late grandmother's yarn; and that scarf, sealing my warmth on a cold morning walk to work, a daily reminder of my antecedents' "walk of fame."

As a neuroscientist, I have endeavored to understand how the brain can form such intricate impressions of the past in our memory. I think that weaving is an apt metaphor for how memory works. If you consider the brain to be a kind of loom, there are ways in which our ongoing experience gets "shuttled" through this loom like threads of yarn. There are also "levers" which get pulled, such that these threads become intertwined into a recognizable form. The product, memory, is a tapestry in which the timeline of our experience becomes warped, and experiences that were initially separated in time are brought together to form a larger story.

In this opinion piece, I hope to illustrate how the way we translate experience into memory is profoundly shaped by narratives. Although this is not an exhaustive review, I provide some context about the science of memory, before elaborating on recent findings about how narratives impact memory. I describe how the hippocampus, a key brain structure for memory, incorporates past memories into our ongoing experience, enabling us to build coherent narratives from events that are otherwise separated in time. I then argue that the way this works suggests that the hippocampus supports a kind of "intertextuality" – that is, new memories are created with reference to other memories, and no memory truly stands alone from other memories. Finally, I speculate on the implications of an intertextual hippocampus.

The science of isolated events

Even if our experiences become part of a larger tapestry in memory, the neuroscience of memory has historically tried to understand how we remember each individual experience. For instance, try to remember what you had for dinner a couple nights ago. In my case, the other night, I had braised noodles with leeks and crab meat. I can imagine myself lifting the noodles to my mouth with chopsticks from a white plate, and then savoring the contents. In the background, I can also envision my spouse and a few take-out trays at our dining table. That is, my brain allows me to not only access the contents of my dinner, but also other associated details from that time which allow me to relive the experience of that specific meal.

This capacity to store and retrieve information that is encountered within specific, time-limited "events", is termed *episodic memory* (Tulving, "Episodic and Semantic Memory"). Seventy years of research has established that episodic memory depends on the hippocampus, a seahorse-shaped structure embedded deep within the brain (see Figure 1). In the 1950s we learned that if you surgically remove someone's hippocampus, they cannot form memories for new events (Scoville and Milner). This kind of deficit was later discovered in many other patients with injury to the hippocampus, and indicated that the hippocampus is necessary for episodic memory (Mishkin et al.; Tulving, "Episodic Memory"; Yonelinas et al.).

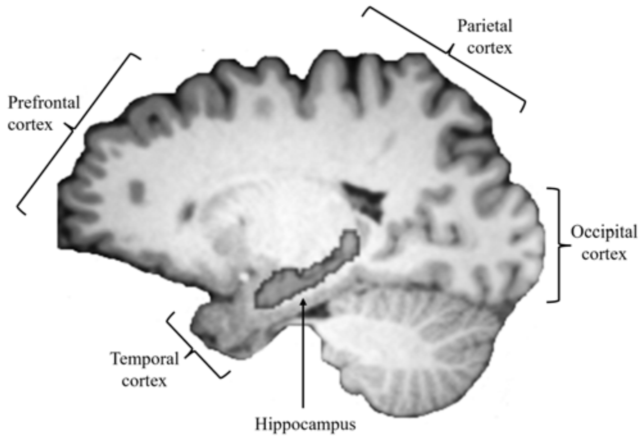

Fig. 1: The figure shows a "slice" through an MRI scan of an individual's brain, with the hippocampus (arrow) traced in dark grey. The cortex (brackets) constitutes the grey ridges and folds covering the surface of the brain's four lobes (frontal, temporal, parietal, occipital).

Subsequently, our field tried to understand *how* the hippocampus supports episodic memory. This endeavor was supported by the advent of functional magnetic resonance imaging (fMRI), a non-invasive technique which allowed us to study how the brain works in healthy individuals without any brain damage. The basic way fMRI works is that we have someone lie down inside a giant magnet, and by perturbing the magnetic field surrounding that person's head, we can read off energy from within their brain. We can then use this energy to construct a series of 3-dimensional "heat maps" which show us how more-or-less active all the parts of someone's brain are, at various moments in time. We can even have someone do different memory tasks during fMRI, and we can then compare the heat maps which correspond to these different tasks to test our hypotheses about how the brain supports memory.

In order to investigate how people can remember specific events, fMRI studies have typically had people memorize series of words or images, manipulating the way these words or images are presented or tested. Although this approach does not approximate the complex nature of real-life events, it has enabled us to conduct well-controlled scientific experiments.

fMRI studies have taught us that the hippocampus supports episodic memory by interacting with the brain's cortex, the complex array of ridges and grooves which cover the surface of the brain (see Figure). We have learned that during an ongoing experience, various regions of the cortex that are connected to the hippocampus support our ability to recognize features like individual people, places, objects, and concepts (Ranganath and Ritchey). The way these co-occurring features come together to comprise an "event" depends on the hippocampus. Much like on a loom, these features are shuttled through the hippocampus and become interwoven to form a memory of the event which took place (Diana et al.).

That said, there is more to weaving than arbitrarily intertwining threads, and memories for individual events are not meaningless packages of co-occurring features. For instance, the dinner I described did not take place in a meaningless void. Actually, we were eating "longevity noodles" to celebrate Lunar New Year. We ordered takeout from our go-to Chinese restaurant because I was coming off a long shift at the hospital, and it was too late to find an available table on their busiest night. As in this example, some studies have suggested that the way one remembers a real-life event can be dependent on one's understanding of surrounding events (Brown and Schopflocher; Burt et al.; Conway and Pleydell-Pearce).

As we now know, the hippocampus does not merely form isolated memories for each event, but also situates them against a backdrop of other events (reviewed in Cohn-Sheehy and Ranganath; see also Addis et al.). To grasp how this works, our science has had to move beyond studying memory for arbitrary words or images. As I will discuss, narratives have unlocked a greater understanding of memory.

Narratives shape memory for events

Many contributors to this journal may find it intuitive that narratives would have a profound influence on memory. However, science progresses incrementally, and our empirical understanding of narratives and memory has had to develop stepwise from basic questions.

Perhaps the most basic question we could ask was, do narratives impact memory at all? This might seem absurd, but try to memorize a series of vague sentences:

> One happens at one time, and one happens later.
> They become a larger whole.
> Putting them together requires one particular region.
> Bringing them back later involves the same region.

It might be challenging to remember these sentences in their present form. However, if I gave you the title, "The hippocampus weaves events into narrative memories," you might find it easier to understand and remember these sentences. Bransford and Johnson had people memorize similarly vague series of sentences, and people who were given a title did a much better job of recalling the sentences than people who were not given a title (Bransford and Johnson). This suggested that the opportunity to form a larger narrative provides a useful basis for remembering smaller pieces of information like sentences.

Narratives not only shape our memory for sentences, but also more realistic events. We know this from subsequent work which investigated how people remember longer stories (Trabasso and Sperry; Trabasso et al.). Stories offered a more realistic way of studying memory, in part because, much like real life, they tend to encompass an extended series of events.

However, not all events in a story are equally important for forming a narrative. For instance, in many stories, there are events which deviate from the main plot as "side events," and contribute less to one's understanding of the larger story. Trabasso et al. found that when people memorized stories, they tended to leave out many, if not all, details from side events, while preferentially recalling main plot events (Trabasso et al.; Trabasso and Sperry). That is, people were more likely to forget the events that were less relevant to a larger narrative. This finding suggested that memory for events might depend on *narrative coherence*: the degree to which individual events can be interrelated within a single narrative (Graesser et al.).

At first blush, it seems reasonable that when we follow the plot of a story, we tend to find it harder to remember unrelated side events. On the other hand, some events that are unrelated to events nearby in time can also be highly related to events that are distant in time. For instance, early in one episode of the sitcom "Seinfeld" (O'Keefe et al.), the character Kramer is seen holding a picket sign outside of a bagel store. Toward the end of the episode, during a dinner with friends, Kramer announces that he has to leave dinner to go bake bagels. Although these events are separated in time, they coalesce to form one narrative: that Kramer was on strike, and now the strike has resolved. In this example, narrative coherence seems to shape our understanding of events that take place at distant times. By extension, narrative coherence might also shape how we remember distant events.

We recently investigated the impact of narrative coherence on memory for distant events (Cohn-Sheehy, Delarazan, Crivelli-Decker, et al.). Toward this end, we created short fictional audiobooks which each recounted a series of events involving some main character. Critically, there were recurring side-characters, who made brief appearances in two separate stories, but these appearances bore no relation to the surrounding main stories—that is, they were "side-plot events." Some of these side-plot events were written to form one coherent narrative (i.e. like the Kramer example from "Seinfeld"). In contrast, other side-plot events were unrelated, and could not easily form a coherent narrative. We reliably found that people could recall more details about the side-plot events which formed coherent narratives, than the side-plot events which could not (Cohn-Sheehy, Delarazan, Crivelli-Decker, et al.). This was even the case when people were asked to recall these events a day after they initially heard the stories.

This finding suggested that, somehow, narrative coherence can bridge the gap between distant events in memory. In other words, new and old events might be interwoven to form a larger narrative tapestry. In order to understand this tapestry, we had to understand the loom.

The hippocampus weaves events into narrative memories

As I mentioned earlier, a preponderance of evidence had suggested that, like a loom, the hippocampus somehow weaves together several pieces of information to create an event in memory. If this loom just passively receives and intertwines threads of yarn, it might be able to string together a series of contiguous events to form a narrative. However, this would not explain the fact that even distant events can form one narrative.

Instead, we suspected that some active lever on this loom might determine whether distant events become interwoven in memory. We tested this idea in an fMRI study which employed the same fictional stories described above (Cohn-Sheehy, Delarazan, Reagh, et al.). We used fMRI to scan the hippocampus while people first heard the stories, and then a day later, while they recalled events from the stories using a microphone in the MRI scanner.

More specifically, for each event in the stories, we used fMRI to characterize an "activity pattern" in the hippocampus. You might think of each event's activity pattern as a square of woven textile containing colored shapes. If two different squares of textile, or events, have an orange circle in the upper-right corner, you could say that these patterns are *similar.* These patterns would be much less similar if one of the textiles had an orange circle in the upper-right corner, and the other had a blue triangle in the lower-left corner. In this fashion, "pattern similarity" provided a proxy for the way that the hippocampus was weaving each event in memory. That is, higher pattern similarity might indicate that the hippocampus was weaving two events together in memory.

Because of the way we designed the stories in our study, we could measure pattern similarity between two distant events that formed a coherent narrative, and we could also measure pattern similarity between two distant events that were unrelated. What we found was that pattern similarity was higher when distant events could form a coherent narrative. This finding provided initial support for the idea that narrative coherence might determine how the hippocampus weaves memories for events.

However, this was not the full story. We thought that there might be something special about the second of two events that form a larger narrative. Rationally, one cannot easily form a narrative across two distant events, until encountering the second event. In our stories, the point where people re-encountered a recurring character provided the opportunity to start drawing connections between distant events. Accordingly, the activity pattern from the second event might hold the key to the whole narrative.

This idea was supported by our data. When someone in our study was later asked to recall both events that formed a coherent narrative, their hippocampus "reactivated" the activity pattern from the second event. In fact, the degree to which someone reactivated this activity pattern not only predicted how well they could remember the second event, but also the first event. This meant that the memory which the hippocampus formed for the second event, somehow incorporated information about the first event, allowing both events to be recalled together. In other words, the hippocampus interwove these two distant events to form one "narrative memory" (Cohn-Sheehy, Delarazan, Reagh, et al.).

Returning to our loom analogy: when two events can form a narrative, it is not just that similar threads are passively shuttled through the loom of memory. Rather, it is at the time of the second event that a lever gets pulled, and the newly shuttled threads of an ongoing memory become interwoven with the threads of a past memory. What results is that the two events which form a narrative are, to some degree, inextricably linked.

Our work demonstrated an important role for the hippocampus in forming narrative memories (see also, Milivojevic, Vicente-Grabovetsky, et al.; Milivojevic, Varadinov, et al.; Collin et al.; Race et al.). However, as I mentioned earlier, the hippocampus does not act alone in creating memory for an event, but also relies on inputs from the brain's cortex. In fact, many studies have suggested that the cortex plays a pivotal role in our ability to understand events in a narrative (e.g. Chen, Leong, et al.; Lee and Chen). That said, the way the cortex supports *memory* for narratives appears to depend on how the cortex interacts with the hippocampus (Chen, Honey, et al.; Barnett et al.; Aly et al.). For instance, within a story, there are moments when people can reliably perceive that one event has ended, and another has begun (Zacks). At these moments, the hippocampus steps up its activity and its interactions with the cortex (Baldassano, Chen, et al.; Ben-Yakov and Henson). This is an active area of study, but one emerging explanation is that at these moments, the hippocampus might retrieve old events or other information from memory which enable one to understand and remember a new event (Chen, Honey, et al.; Lu et al.). That is, even if the cortex is continuously shuttling threads of meaningful information about an ongoing story through the loom of memory, it is likely the hippocampus which serves as the dynamic, lever-pulling aspect of this loom, determining how those threads are interwoven.

As I will now argue, our new understanding of the way the hippocampus constructs narrative memories dovetails with a longstanding idea about literature.

The hippocampus supports intertextuality

Many literary theorists have proposed that the way people comprehend and create texts is highly dependent on how each text relates to other texts, an idea referred to as *intertextuality* (for a review, see Alfaro). This idea has been applied to many kinds of "texts," including stories, films, music, and other art forms. One version of this idea is that no new text is completely original, because it is necessarily built upon prior texts and can only be comprehended in relation to other texts. This echoes what I have just described about memory and the hippocampus. The way the hippocampus creates memories for each event is built upon memories for other events, and dependent on how events are collectively situated within a larger narrative. Intertextuality may be a property of episodic memory, with a biological basis in the hippocampus.

Perhaps the clearest way to illustrate how intertextuality might be playing out in memory, is to consider how intertextuality plays out in literature through the use of allusions. For instance, in James Joyce's *Ulysses*, recognizing that a belligerent pub customer named "the Citizen" is an allusion to the "Cyclops" from Homer's *Odyssey* transforms what would otherwise be a liquor-fueled argument into a death-defying struggle for survival (Joyce, *Ulysses*). In real-life, not all of us are graced like Joyce with constant access to literary allusions. However, we often experience *reminders* which, equivalently, enable us to draw connections between events (Wahlheim and Jacoby; Ross and Bradshaw; Jacoby). If you encounter a person or object that you previously encountered in a past event, this can serve as a reminder of that past event and provide an opportunity to draw connections between the two events. Moreover, by conjuring information about the past, reminders can effectively embed information about the past within a new memory for the present. This supports an intertextual view of memory, in that new memories are necessarily dependent on, and understood in relation to, old memories.

Furthermore, we know that the hippocampus responds to reminders in ongoing events. When fMRI experiments present people with a recurring word or image, the hippocampus supports the ability to retrieve information about previous events involving that word or image. Through this process, the hippocampus can embed information about the previous event into a memory for the new event, allowing the two events to become linked in memory (Horner et al.; Zeithamova et al.). However, in contrast, other studies have shown that when events share overlapping words or images, the hippocampus will effectively keep those events *separate* in memory (Chanales et al.). That is, not all reminders lead the hippocampus to interweave events (see also Stawarczyk et al.).

Our work provides some insight into the conditions which encourage the hippocampus to interweave events (Cohn-Sheehy, Delarazan, Reagh, et al.; Cohn-Sheehy, Delarazan, Crivelli-Decker, et al.). In the stories we constructed, recurring fictional characters could serve as a reminder of distant events involving those characters. When this kind of reminder could lead to the formation of a coherent narrative, the hippocampus embedded information about the prior event within the memory of the new event. That is, reminders can lead the hippocampus to draw connections between events in memory, but this may specifically depend on narrative coherence. This parallels the way literary allusions shape the narrative of a new text.

Intertextuality is not limited to allusions which shape the meaning of new texts. Intertextuality can also involve reshaping one's understanding of older texts in light of newer texts (Alfaro). Although I have just illustrated how new memories are shaped by old memories, the reverse can also take place. For instance, when you are presented with a new insight about past events, the hippocampus can alter your memory for those past events to accommodate the new insight (Milivojevic, Vicente-Grabovetsky, et al.). In fact, when you re-watch a film, but with a changed ending, this can even lead the hippocampus to incorporate false details into your memory for the original film (Sinclair et al.). In other words, in both good and bad ways, the hippocampus might update old memories to fit an evolving narrative about a collective set of experiences. This mirrors the idea that the collective set of texts we have experienced shapes our understanding of any individual text.

It is worth noting that these kinds of reminders and insights tend to involve some degree of conscious awareness. However, intertextuality can take place even without conscious awareness, and many texts contain similar types of narratives even without any conscious source attribution. For instance, both James Joyce's *Ulysses* and Homer's *Odyssey* depict a kind of "hero's journey," a storytelling format that may have derived from ancient mythology and oral tradition (Campbell and Moyers). In a similar vein, many real-life events unfold in a predictable way, and our memories can become shaped by complex knowledge about how these events tend to unfold (Rumelhart; Thorndyke; Mandler and Johnson; Pichert and Anderson; Ghosh and Gilboa). For instance, when you go to a restaurant, you can draw from a restaurant "script" to predict that you will first be sat at a table, then order food, then receive and eat food, and finally pay and leave (Schank and Abelson). Much like reminders, scripts can provide relevant past information which enables one to understand a new event. However, in contrast to reminders, scripts are learned across multiple past events rather than referencing a single event. Furthermore, scripts do not capture other unique details of an event, like who you were with or what you were eating.

Recent evidence suggests that areas of the cortex which support our ability to understand narratives, can also support information about scripts like going to a restaurant (Baldassano, Hasson, et al.; Reagh and Ranganath). These findings are in line with the idea that the cortex can provide support for complex knowledge and concepts which are derived from prior events, but not consciously tied to specific past events in memory (e.g. O'Reilly et al.; Gilboa and Marlatte). However, recent evidence suggests that in contrast to the cortex, the hippocampus supports the ability to construct memories which merge information about scripts with other unique details that take place during conscious awareness of an event (Reagh and Ranganath). In other words, even if one unconsciously draws upon scripts or other past information, the hippocampus may be responsible for weaving this information into one's conscious memory of a new event or text.

In summary, the hippocampus may provide support for a spectrum of conscious and unconscious forms of intertextuality. At one extreme, the hippocampus may support a conscious synthesis of information about past and present experiences to form a narrative in memory. At the other extreme, the hippocampus may even incorporate unconscious forms of past information into the conscious memory of a present experience. In either case, the hippocampus provides a mechanism by which memories for any, or all, experiences, are shaped by other experiences. To the degree that our many experiences form a narrative tapestry, intertextuality may be a property which determines how we create and understand this tapestry. I will now speculate about what this means for life and for art.

Implications of an intertextual hippocampus

At this point, you may be wondering what neuroscience has actually taught us about narratives or intertextuality. Fiction writers have long been able to capture how intertextuality manifests in our conscious day-to-day experience (e.g. see Joyce, *Ulysses*). Hip-hop artists have mastered the use of lyrical allusions and audio sampling to build intertextual meaning. And introspectively, after one has lived many years, it is hard to imagine that any new event will not resemble some prior event or predictable script. Is the science simply confirmatory?

What science has to offer is an objective test of how these things work. As a result of tedious experiments, we have empirical evidence to suggest that intertextuality is more than a concept in theory, but a biological reality. Any time you experience a new event or text, the intertextual machinery of your hippocampus may be conjuring past events or texts, bringing them to bear on how you understand and remember each new experience.

This might have both positive and negative consequences. In some cases, intertextuality may be beneficial for memory. Being able to recognize that new and old events form a narrative can make it easier to remember those events in detail (Cohn-Sheehy, Delarazan, Crivelli-Decker, et al.). Additionally, your previous experience with texts can make it easier to understand and remember similar texts. For instance, people with a strong background knowledge of "Star Trek" find it easier to memorize new fiction involving "Star Trek" characters (Long and Prat).

Conversely, when one cannot easily draw connections between old and new events or texts, this can negatively impact memory. In the early twentieth century, F.C. Bartlett presented a Native American story called "War of the Ghosts" to English participants who had no prior experience with Native American literature. When Bartlett asked the English participants to recall the story, they forgot many of the original details. Furthermore, the more times they retold the story, the more it became distorted to sound like a typical English war story of that time (Bartlett). In other words, when we are unable to refer to a relevant past experience or text, intertextuality might actually lead us to form narratives or memories that may sound like they are true but are actually false.

I have mainly focused on how the hippocampus might support intertextuality for a reader. However, the same principles may also apply to the side of the author. In fact, we know that beyond its role in memory, the hippocampus also supports the ability to imagine possible events that have not yet taken place (Addis, Wong, et al.). That is, the ability of authors to construct new texts about possible events may also rely on the same intertextual machinery (Benedek et al.). If so, this may have positive consequences for the creative process, especially for an author like James Joyce who intended to create something new by consciously building upon past texts.

On the other hand, when this same machinery draws upon unconscious sources, it might contribute to unconscious plagiarism by authors. In a famous example, George Harrison produced and released the song "My Sweet Lord" without realizing that it contained a combination of motifs and chord progressions that had previously characterized The Chiffons' "He's So Fine". Memory researchers have often interpreted this example as a failure of "source monitoring," a conscious process that enables one to discern where a memory came from (Johnson). Source monitoring is largely thought to be supported by the prefrontal cortex (Johnson; see also Shimamura; Moscovitch and Winocur), an area of the cortex which is known to dynamically interact with the hippocampus in various memory processes. However, while a source monitoring account might explain some lack of awareness during Harrison's creative process, it arguably does not account for the intertextual synthesis that the creative product represents. Somehow, Harrison incorporated motifs and chords from an unconscious source, a love song about infatuation, into the conscious creation of a unique spiritual love song about his relationship with God. This type of synthesis may have depended on the intertextual machinery of the hippocampus. Furthermore, listeners may not have even recognized "My Sweet Lord" as a form of plagiarism without an intertextual hippocampus that reminded them of "He's So Fine."

Whether or not intertextuality benefits memory or art, it is pervasive in our lives. Recent work from Bellana et al. demonstrated that when we deeply engage with a story, it can linger in mind for a long time and even influence our spontaneous thoughts (Bellana et al.). Even the seemingly random thoughts we have in our day-to-day lives might actually draw upon some literary influence. By a logical extension of this finding, it might be impossible to completely separate out thoughts that we think are original, from thoughts which reflect a memory for past stories. Intertextuality might be so deeply wired into how the brain processes our experiences, memories, and thoughts, that it usually goes unnoticed.

It is worth asking *why* intertextuality would be a property of the brain. One possibility is that, through our upbringing and education, we are so immersed in stories—through literature, films, music, and day-to-day conversation—that by some age, our brains have adapted to the task of remembering a massive set of interrelated narratives. The more our literature has evolved, the more it may have evoked some innate capacity of our brains for intertextuality and narrative memories. In turn, by harnessing the power of stories, neuroscience may further elucidate the facts about our "uncreated conscience" (Joyce, *A Portrait of the Artist as a Young Man*).

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