

Brain activity is a complex interplay of biological and cognitive processes that are vital to human functioning. The human brain is frequently referred to as the most intricate organ in the body, in addition, it has several specialty regions that are interconnected by an intricate network of neurons (Honey et al., 2010). It is responsible for regulating a wide range of functions, from fundamental physiological processes to complex cognitive operations. As a result, impairment to a particular area of the brain may cause a disturbance in this intricate equilibrium, triggering a series of biochemical and cognitive consequences that have extensive ramifications for the overall welfare of the affected individual (Pessoa, 2014). As the highlighted region of the brain illustrated in the image is presented, focus shifts to the hippocampus, with particular emphasis on the left hippocampus. The hippocampus, an intricacy-shaped structure resembling a seahorse situated in the medial temporal lobe of the brain (Deshmukh & Knierim, 2012), is vitally involved in a multitude of cognitive processes, with a particular emphasis on memory and spatial navigation (Eichenbaum, 2017; Rao et al., 2022). Prior to this, the hippocampus is an intricate cerebral structure situated profoundly within the limbic lobe (Dhikav & Anand, 2012). This anatomical arrangement is consistent with the results reported by Chauhan et al. (2021), who similarly emphasise that the location of the hippocampus in the limbic lobe strengthens its association with the limbic system, an assembly of brain structures that governs behaviour, memory, and emotion. Moreover, from a structural standpoint, it can be divided into two discrete regions: the dentate gyrus, which is primarily composed of granule cells distributed in molecular and granule cell layers and it consists of fascia dentata and hilus (Cherubini & Miles, 2015; Fogwe et al., 2023) and the Cornu Ammonis (CA1-4) (Cherubini & Miles, 2015; Rao et al., 2022).

Furthermore, the hippocampus contributes substantially to the formation of new memories, especially episodic memories, which pertain to specific events or experiences associated with a particular location and time (Moscovitch et al., 2017; Burgess et al., 2002). Zhong et al. (2019) stated that it aids in the consolidation of these memories by facilitating their transfer from short-term memory (STM) to long-term memory (LTM) storage. Supporting this claim, Sakaguchi and Sakurai's (2020) research revealed that both the left and right hippocampus are involved in STM, with the right hippocampus supporting and inhibited by the left hippocampus. Additionally, they suggested that the left hippocampus may primarily support LTM under conditions of sufficient neural activity. The term STM referred to as a storage system that consists of numerous subsystems with restricted capacity, in contrast, LTM preserves information over time, perhaps for a lifetime, where it has a large

capacity and stores an array of memories, including personal experiences, facts, and abilities (Cascella & Al Khalili, 2023). It shows that the hippocampus plays a crucial role in memory processes, shaping cognitive abilities and experiences. Damage to this area can significantly impact memory function and cognitive well-being. Thus, the main objective of this essay is to perform an in-depth discussion of the biological and cognitive effects that arise from the damage of the hippocampus. In addition, through the synthesis of theories and empirical evidence, it aims to enhance comprehension regarding the ramifications of brain damage on cognitive abilities and biological mechanisms.

The hippocampus is a critical brain structure, and any damage to it can have significant biological consequences that go beyond just cognitive decline. Also, the hippocampus plays a vital role not only in cognitive processes, but also works as a central point for many biological functions within the brain (Maguire & Hassabis, 2011). From a biological standpoint, due to the hippocampus's casual involvement in consolidation (Schapiro et al., 2019), in which the process of memory consolidation is profoundly affected, specifically the transformation of short-term to long-term memories (Squire et al., 2015). The term "consolidation" defined by Moscovitch & Gilboa (2022), is a psychological phenomenon that involves a time-dependent process which strengthens learning or memory, making it less vulnerable to being disturbed or lost by future occurrences. As can be seen in H.M.'s case, the incapacity to develop new memories was caused by hippocampal removal by studying it over time. Despite maintaining some earlier memories, H.M. failed to develop new long-term memories, demonstrating that the hippocampus was crucial to storing short-term memories (Squire & Wixted, 2012). Pinel & Barnes (2022) also mentioned that the case of H.M presented empirical support for the notion that the hippocampus imposed a distinct influence on memory consolidation.

In addition, the Standard Consolidation Theory (SCT) can provide insight into the impact of hippocampus damages by elucidating how episodic and semantic memories, which are initially reliant on the hippocampus but ultimately undergo consolidation in their original configurations in other cerebral regions, can be of assistance (Winocur & Moscovitch, 2011; Pinel & Barnes, 2022). Furthermore, SCT illuminates the temporal gradient of retrograde amnesia, which reveals that patterns of memory loss observed in individuals with hippocampal injury are more pronounced in recent memories than in older ones (Bright et al., 2006; Clark et al., 2002). Nevertheless, an alternative perspective on memory consolidation

emerges from the Multiple Trace Theory (MTT) (Nadel & Moscovitch., 1997), which stands in contrast to the SCT. MTT indicates that memories are preserved in several dispersed traces throughout the brain (Nadel et al., 2000; Yassa & Reagh, 2013). This idea suggests that in the event of hippocampal dysfunction, memories can still be accessed by activating other brain areas responsible for memory storage and retrieval. Hence, by incorporating both SCT and MTT, a holistic comprehension of the effects of hippocampal damages on memory consolidation processes can be attained.

Other than memory consolidation, neurogenesis regulation is dependent on the hippocampus (Leal-Galicia et al., 2019); damages to this region can interfere with the complex molecular and cellular mechanisms underlying this process. Fares et al. (2018) defines neurogenesis as the transformation of precursor cells into functional neurons, which was previously believed to occur exclusively in mammals during the embryonic and prenatal phases. Moreover, adult hippocampal neurogenesis appears to be intricately linked to certain types of hippocampus-dependent learning and memory of new information, according to accumulating evidence, as stated by Yau et al. (2015). Also, they mentioned that memory formation, maintenance, and acquisition are all enhanced when adult neurogenesis in the dentate gyrus of the hippocampus is increased. It can be seen that hippocampus damage can result in a reduction in neurogenesis, and it may hinder the brain's capacity to acquire new information, to form new memories, and adapt to environmental changes (Demars et al., 2010). Furthermore, Rao et al. (2022) concluded that, when there is adult neurogenesis impairment, it may be a crucial risk factor for neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease. Equally important, mood regulation and affective processing are additional functions of the hippocampus (Weissman et al., 2021). Hence, mood disorders, including anxiety and depression, may result from the disruption of the functions caused by damage to this region, and this was demonstrated by Sapolsky's (2004) study, which concluded that impaired neurogenesis contributes to the development of depression.

Besides biological effects, the precise nature of the cognitive effects may differ contingent upon the location and extent of damage imposed on the left hippocampus. Left hippocampus damage is frequently linked to the following cognitive effects, such as, verbal memory impairment (Alessio et al., 2006; Richardson et al., 2003). Verbal memory refers to as an general term denoting the capacity to recall information presented verbally and its

capability can be assessed through a range of tasks, such as words list learning, story recall, and word sequences learning with paired words (Tatsumi & Watanabe, 2009). It can be seen that verbal memory can be profoundly affected by damage to the left hippocampus, given its vital function in the processes of encoding, retaining, and retrieving linguistic information (Kenser, 2018; Pereira et al., 2010). Similarly, in the study by Khlif et al. (2021) examined anatomical asymmetries in hippocampal volumes in relation to different neurological conditions, concluded that a strong correlation was seen between reduced volumes of the left hippocampus and worse performance in verbal memory. By facilitating the formation of associations between words, their meanings, and contextual information, this region promotes the efficient recall of verbal material. Nevertheless, in the event that this area is compromised, a study by Wang et al. (2022) also concluded that individuals encounter difficulties in encoding novel verbal information, which could hinder the consolidation and storage of verbal memories and potentially compromise retrieval.

Furthermore, another notable cognitive effect linked to damage of the left hippocampus is episodic memory impairment. Episodic memory, defined as an essential element of human cognition, empowers individuals to recollect particular autobiographical occurrences and experiences, encompassing the temporal, spatial, and accompanying affective aspects (Sugar & Moser, 2019; Das et al., 2019). Also, Sugar & Moser (2019) highlighted where the network of interconnected brain regions, including the hippocampus and adjacent parahippocampal regions, is vitally important for the formation of episodic memories of such events. It has been shown that adverse effects on the ability to retrieve such memories, including difficulties with daily activities and disruptions to one's sense of self and continuity, can result from damage to the left hippocampus (Koenig et al., 2018). Furthermore, a study conducted by Geib et al (2017) into the function of integrative processing in the recollection of episodic memories reached the conclusion that impairment to this particular area hinders the encoding procedure, resulting in challenges when attempting to reconstruct new episodic memories that include verbal information. Thus, it can be difficult for some individuals to recall conversations, names, or other linguistic elements associated with past events. A more comprehensive analysis of episodic memory deficits in academic discourse can be achieved through the application of the principles of the MTT.

According to Nadel et al. (2000), the idea of MTT is that the hippocampus is constantly engaged in preserving and retrieving memories, particularly episodic memories,

which are specific, detailed recollections of events. Also, they stated that retrieving these memories continues to require the hippocampus, even after a sufficient amount of time has elapsed. Furthermore, in accordance with the MTT, the formation of memory traces during learning experiences is how memories are encoded (Nadel & Hardt, 2011). Additional evidence in favour of the MTT is provided by research such as that of Frankland et al. (2019), which revealed that the hippocampus remains involved in memory retrieval processes for an extended period of time following initial encoding. Moreover, Preston & Eichenbaum (2014) states the establishment of new memory traces, which are responsible for encoding long-term memories, can be challenging for those who have suffered a hippocampal injury. As a result, they may counter difficulties in acquiring new information or recalling recent events. Another evidence from a study exploring the effect of hippocampal damage in children on recalling the past and imagining new experiences by Cooper et al. (2011) concluded that, individual who had suffered hippocampal were only able to offer a general depiction of an event; incapable of providing precise spatiotemporal context and when asked to recollect previously imagined scenarios, they generally made new ones instead of using their limited memory. Hence, it can be seen in the context of MTT, individuals who have sustained such damages may encounter challenges in establishing fresh memory traces, which can manifest as difficulties recalling recent events or acquiring new information.

Now shifting attention to the advantages and constraints of the theory examined in this essay. Firstly, one of the key advantages of the SCT is its capacity to furnish a temporal structure that facilitates comprehension of memory consolidation. According to SCT, the hippocampus is initially responsible for the rapid encoding of memories, but as time passes, these memories become more consolidated and dependent on cortical structures. This temporal component of SCT provides an explanation for why, with the passage of time, memories that were once susceptible to disruption by interference or brain damage become more stable and resistant to interference (Sekeres et al., 2018). However, a constraint of the SCT is its linear, overly simplistic conception of memory consolidation. Over time, memories progressively shift from relying in the hippocampus to cortical structures, according to SCT (Nadel & Bohbot, 2001). Nevertheless, this model fails to account for the dynamic nature of memory consolidation, which includes interactions across brain areas as well as continual reorganisation. Next focus on an analysis of the advantages and constraints of the MTT. The MTT provides a holistic comprehension of memory mechanisms by proposing that memories are dispersed throughout interrelated regions of the brain. This functionality facilitates the

depiction of diverse memory types and their ever-changing interactions. Moreover, Sutherland et al. (2019) stated that the MTT provided a more precise differentiation between episodic and semantic memories with respect to the consolidation system, also, they highlight how the MTT framework assisted in comprehending observations indicating that retrograde amnesia (RA) frequently lacked temporal gradienting, which would imply that older memories did not inherently possess greater resistance to disturbance than more recent ones. Although the MTT is widely acknowledged for its valuable contributions, it is imperative to recognise that it is not without its limitations. As stated in a study by Moscovitch & Gilboa (2022), the insufficient attention given by the MTT to the role of the hippocampus in distant episodic memory, while disregarding other critical facets of memory processing. Contrary to MTT's focus on current memories, they discovered persistent hippocampal activity throughout distant episodic memory recall, suggesting continuous hippocampus involvement. Thus, both theories provide insights into the effects of hippocampus damages, but SCT's temporal structure overlooks dynamic processes and MTT neglect of the hippocampus's role in distant episodic memory.

Ultimately, the hippocampus is an essential structure for both biological and cognitive functions, especially in the creation and strengthening of memories (Perosa et al., 2020; Banker et al., 2021). Impairments to this complex structure can result in notable cognitive deficiencies, such as difficulties in verbal and episodic memory, as well as emotional disorders as discussed in the essay. Specifically, the cognitive impacts of this have significant practical consequences, affecting an individual's capacity to participate in everyday tasks (Lövdén et al., 2020), sustain social interaction, and overall well-being (Samtani et al., 2022). The evidence shown in the study conducted by Banker et al. (2021) examines the current body of evidence concerning the involvement of the hippocampus in Autism Spectrum Disorder (ASD). The study puts forward a hypothesis proposing that impairments in the functioning of the hippocampus, specifically in cognitive process, could be responsible for the deficiencies in social interaction, memory, and spatial reasoning observed in individuals with ASD. Moreover, Bakkour et al. (2019) reached the conclusion that the duration of deliberation has an impact on activity, which implies that the region contributes to the formation of value-based decisions. This is supported by fMRI analysis in healthy participants and a comparison with patients who have hippocampal damage, who demonstrate longer reaction times and more longer decisions.

As a result of these findings, it is critical to investigate potential treatments for hippocampal injury in order to mitigate the cognitive deficits that accompany. An area of potential interest pertains to cognitive rehabilitation (CR) initiatives that are customised to focus on particular cognitive functions that are impacted by hippocampal dysfunction. Also, CR involves a neuropsychological evaluation to identify strengths and deficits and restrains skills and teaches compensatory methods (Tsaousides & Gordon, 2009). Hence, CR has the potential to restore recognition memory, according to Van Paasschen et al. (2013), following a comprehensive examination. Other than CR, neurostimulation methods, such as transcranial Direct Current Stimulation (tDCS), present encouraging prospects for the therapeutic intervention of hippocampal impairment (Kaviannejad et al., 2022). Non-invasive techniques that target specific brain regions, such as the hippocampus or its connected areas, employ electromagnetic fields to modulate neural activity. Bjekić et al. (2021) highlight the developing potential of tDCS as a non-invasive method for enhancing memory functions, among the many techniques currently employed in this domain. Thus, tDCS exhibits considerable potential as an extra-invasive approach to enhance memory function through the modulation of neural activity in the hippocampus and its interconnected areas. Overall, the complex relationship between biological mechanisms and cognitive processes highlights the crucial significance of the hippocampus. This emphasises the need for more research and creative interventions to reduce the significant effects of hippocampal damage on memory, cognition, and overall well-being.

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