


# Across the Boundary: The Formalization of the Interface Between Episodic Memory and Narrow Syntax Computation of Human Language

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Biolinguistics, 2024, Vol. 18, Article e14649, <https://doi.org/10.5964/bioling.14649>

**Received:** 2024-05-15 • **Accepted:** 2024-06-09 • **Published (VoR):** 2024-08-06

**Handling Editor:** Patrick C. Trettenbrein, Max Planck Institute for Human Cognitive and Brain Sciences & University of Göttingen, Germany

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## Abstract

A growing number of studies indicate that the hippocampus plays an essential role in language processing as well as episodic memory. However, there is no consensus on how it is engaged in both domains and how it connects the two domains. From a theoretical perspective, this paper delves into the intricate relationship between episodic memory and the narrow syntax of human language. To be more specific, I focus on the functions of the hippocampus in event processing and propose that hippocampal phasic activity supports the cyclic interaction between episodic memory and narrow syntax. Through such cyclic interaction, the event in the episodic memory is assigned a linguistic format that can be communicated, while narrow syntax is provided with an interpretative engine that underlies reference. This hypothesis predicts that when episodic memory is impaired, corresponding abnormalities appear in linguistic reference.

## Keywords

hippocampus, episodic memory, narrow syntax, phase theory, interface, reference



Out of the same storehouse, with these past impressions, I can construct now this, now that, image of things that I either have experienced or have believed on the basis of experience—and from these I can further construct future actions, events and hopes; and I can meditate on all these things as if they were present...

St. Augustine, *The Confessions*, Book 10, Section 8.14

## 1 Introduction

In the field of neurocognition, memory and language are traditionally viewed as separate psychological constructs with distinct neural underpinnings. While the study of language mainly focuses on mechanisms that are assumed to be domain-specific (Zaccarella & Friederici, 2015), memory on the other hand is considered to be dependent on domain-general processes (Campbell & Tyler, 2018). For example, the *what*, *where*, and *when* components of episodic memory are assumed to involve neural mechanisms across various cognitive domains (Park et al., 2023). Through highlighting the functions of the hippocampus in event processing, the intricate relationship between narrow syntax—the core syntactic operation of language—and episodic memory will be explored in this paper.

Episodic memory was originally defined as memory for personally experienced past events. It contains information about the details of past events, including what, when, and where (Tulving, 1972, 1985), and enables us to mentally time travel to re-experience the events that happened to ourselves. One essential part of episodic memory is autonoetic consciousness, which accompanies the process of memory retrieval and serves as the essential ingredient in shaping how we perceive ourselves in subjective time (Conway & Pleydell-Pearce, 2000; Tulving, 2002). In this sense, episodic memory is, by its nature, indexical (Hinzen, 2014), since it involves events specified for time and place and in relation to the first-person experiencing.

Further, episodic memory is not merely an accurate record of a past event (Dokic, 2001; Klein et al., 2004). Episodic memory exhibits the ability to flexibly recombine information from past experiences and imagine potential future events, which in turn could guide behaviors in new situations (Allen & Fortin, 2013). This psychological process is also called ‘scene construction’, which supports recollective experience (Hassabis & Maguire, 2007, 2009). This process also necessitates self-projection, which is defined as ‘the ability to shift perspective from the immediate present to alternative perspectives... imagined future environment... referenced to oneself’ (Buckner & Carroll, 2007, pp. 49). Meanwhile, Mahr and Csibra (2018) suggest that episodic memory also provides grounds for belief, which contributes to the stabilization of human communication. As Dokic (2001) noted, ‘genuine episodic memory gives the subject [...] a reason to believe that the information carried by it does not essentially derive from testimony or inference but comes directly from the subject’s own past life’ (p. 4; see also Mahr & Csibra, 2018 for relevant discussion and a comprehensive list of relevant references). In this sense, these

properties are closely related to the sense of self in Tulving's original ideas of mental time travel.

The narrow syntax of human language and episodic memory have some similarities. For example, both are generally assumed to be generative systems that provide constructional principles and can be applied productively. This leads some linguists to question why syntax ('grammar' in Hinzen's terms) should not be considered similarly to the underlying mechanism found in episodic memory (Hinzen, 2014). However, the research tools at our disposal in the past, such as domain-specific grammatical rules, could not provide a convincing explanation for these similarities in an interdisciplinary context. As a result, these similarities were relegated to syntax and memory interface issues that many linguists wanted to avoid. Nevertheless, it is an undeniable fact that with linguistic tools, we can express indexical reference to an episodic event specified for time and place, as well as grammatical person distinctions that are relevant for a first-person perspective.

Language also influences episodic memory in other aspects. For example, language is involved in the process of encoding and retrieving episodic memory (Wang & Gennari, 2019), making it easier to be accessed and shared. When we narrate a past event to a friend, language is not only used to capture and articulate the details of the events but also to reinforce the memory itself. The ability to describe an event accurately not only requires the retrieval of the details of the event but also the sequencing of the events, both of which are realized through language and its specific format that narrow syntax provides. As Neisser (2008) noted, "Remembering is not like playing back a tape or looking at a picture; it is like telling a story" (p. 88). When we make a coherent and meaningful narration of a series of events through the constructional mechanisms of language, we create a structured representation of that experience in our minds. Without the narrow syntax of language, the sensory input about the event we experience—the time, people, and places—could remain fragmented and disconnected. Hence, the narrow syntax of language could provide a mechanism and the corresponding format for us to describe, make useful references as links between events, and make our experiences into meaningful chunks. In this sense, and from a theoretical linguistic perspective, the narrow syntax of language is not a domain-specific associative operation but serves as domain-general organizational principles to express the properties of episodic memory linguistically. In sum, the narrow syntax of language serves not only as a tool for expressing episodic memory but also for feeding episodic memory by providing a format of organization.

From a theoretical perspective, how the connection between the narrow syntax of language and episodic memory is built will be explored. To be more specific, I will focus on the functions of the hippocampus in event processing and suggest that the phasic activity of the hippocampus at the event boundary provides a shared neurological basis where seemingly distinct cognitive domains interface. The research hypothesis is

that episodic memory provides one of the interpretative engines for language, while the mechanism of narrow syntactic computation of language provides an organizational format for episodic memory. Both domains together contribute to reference in human language and free it from lexicalized concepts that are detached from context and personal experiences. Due to their linguistic format, cognitive flexibility and creative thoughts can be shared socially. Of course, I am not suggesting that language is the only source for providing a format for episodic memory. Instead, I would like to highlight the close connection and a domain-general mechanism between them when event representation is generated. The paper is organized as follows. In Section 2, the details of the Declarative/Procedural Memory Model (DP) by Ullman and colleagues and the differences between episodic memory and semantic memory will be reviewed. Based on the distinctions between the hippocampus's functions assumed in this paper and in the DP model, the reason why episodic memory has been chosen as the research target rather than semantic memory will be explained. Section 3 mainly deals with the issues related to linguistic phase theory and suggests that the functions of the phase edge in reference could be mapped onto the functions of the hippocampus. In Section 4, I illustrate the Language-Episodic Memory Interface Model and provide possible evidence from the studies on brain oscillation. Clinical evidence is presented in Section 5. In Section 6, I list several possible cases that may refute the hypothesis in this paper and future directions to test the hypothesis on practical ground.

## 2 The Functions of Hippocampus in Memory and Language

The memory system and the language system are often thought of as two separate cognitive modules and psychological constructs. Due to the seeming uniqueness of language, the theories and research conducted within the linguistic discipline mainly focus on domain-specific representation, processing, development and neurological underpinnings. This leaves us without paying enough attention to the neural and computational mechanisms that are shared between language and other cognitive systems in humans and animals (Ullman, 2004, 2016). Research on the evolution and functions of subcortical structures of the human brain suggests that analogous computation may underlie language and other cognitive domains. Take the hippocampus, for example: studies indicate that the functions of the hippocampus support spatial navigation (Jin et al., 2020) and online syntactic processing (Piai et al., 2016; see also Murphy et al., 2022 for related discussion). In a series of works, Ullman and colleagues suggest that the memory system is an indispensable part of language processing. In the following section, I will first review Ullman's Declarative/Procedural Memory Model (DP) model. Based on the functions of the hippocampus, I will elucidate our viewpoint and its differences from the one stated in the DP model.

## 2.1 Declarative/Procedural Memory Model (DP) and its Relation to the Functions of the Hippocampus

Ullman's DP model posits that the two memory systems have distinct roles in language processing. Declarative memory (long-term memory) is assumed to underlie the storage and retrieving of factual, event-based knowledge and episodic memories. It facilitates the retention and recall of both vocabulary and grammatical knowledge. The declarative memory system mainly depends on the medial temporal lobe, hippocampus, and surrounding cortical regions. Procedural memory underlies the learning and automatic execution of new sensorimotor and cognitive 'skills' (Schacter & Tulving, 1994). It subserves the rule-governed combination of lexical items into complex structures. Procedural memory guides the actual production and comprehension of speech. The system is often termed as an 'implicit memory system' because both the acquisition of knowledge and the knowledge itself are typically inaccessible to conscious awareness. Basal ganglia serve as one of the major subcortical bases for procedural memory (Ullman, 2001a, 2001b, 2004). The interaction of declarative and procedural memory systems constitutes a dynamically interconnected network that results in both collaborative and competitive learning and processing, which underlie linguistic processing (Poldrack & Packard, 2003).

In the DP model, the authors also mentioned the involvement of the hippocampus in syntactic processing and cited the fMRI investigation by Opitz and Friederici (2003). However, the hypothesis on the functions of the hippocampus pertains solely to the early stages of acquisition, when proficiency is low. In contrast to this approach, I emphasize the real-time involvement of the hippocampus in syntactic processing and the interaction between episodic memory and syntax. As Duff and Brown-Schmidt (2012, p. 2) noted, 'hippocampus-dependent declarative memory system as a whole has received considerably less attention as a potential candidate memory mechanism supporting online language processing, that is, the incremental processing of language as it unfolds in real-time'.

Before delving into episodic memory, it is also necessary to clarify the difference between episodic memory and semantic memory, because semantic memory is often mentioned in linguistic research. In the following section, I will explain why I chose episodic memory as the research target in this article. Subsequently, I will further explore how the hippocampus processes events within episodic memory.

## 2.2 The Distinction Between Semantic Memory and Episodic Memory

Semantic memory and episodic memory are two distinct forms of long-term memory that play crucial roles in our ability to acquire, store, and retrieve information about the world. The distinction between semantic memory and episodic memory can be traced back to Tulving (1972). Tulving introduced the concept of episodic memory to describe

the recollection of specific events and experiences tied to a particular time and place. He contrasted this with semantic memory, which is associated with meaning or knowledge that primarily pertains to language. Semantic memory was defined as the storage of general knowledge and factual information not tied to specific events. Episodic and semantic memory are assumed to operate in different ways and serve different functions in cognitive processing (Tulving, 1983).

The distinction between semantic memory and episodic memory has a crucial role in deepening our comprehension of human memory and cognition. Nevertheless, it's important to recognize that such distinctions can sometimes be ambiguous. For instance, autobiographical memories frequently encompass both semantic and episodic components, indicating a complex interaction between these two memory types. Furthermore, recent research suggests that semantic and episodic memory may rely on overlapping neural substrates, challenging the notion of distinct memory systems. Even though the hippocampus is widely assumed to be related to episodic memory, studies report that the hippocampus is also involved in the processes of lexical retrieval (Hamamé et al., 2014) and lexicalization (Takashima et al., 2014). Research on developmental amnesia has demonstrated that individuals with hippocampal atrophy experience challenges in acquiring new semantic memories (Duff et al., 2020). Be that as it may, semantic memory is generally thought to be closer to human language than episodic memory because animals generally lack what is traditionally defined as language, while from an evolutionary perspective, the relationship between episodic memory and language has been explored in various studies (Corballis, 2019; Corballis & Suddendorf, 2007). As an evolutionarily conserved brain structure, the hippocampus is essential for us to gain a deeper understanding of the evolutionary trajectory of human language and the underlying computational mechanism that is shared between language and episodic memory.

### 2.3 Hippocampus and Episodic Memory

It has been well established that the hippocampus (and the medial temporal lobe structures) play a critical role in the formation and retrieval of episodic memory (Eichenbaum & Cohen, 2004; Graf & Schacter, 1985; Kinsbourne & Wood, 1975; Tulving & Markowitsch, 1998; Wiltgen et al., 2010). Instead of serving as the neurological hub for memory storage, a hippocampus-based event construction process integrates different aspects of an event, such as time, space, sensory input, and emotional responses, into a coherent representation (Cowell et al., 2019, p. 5). This function, known as relation binding, indicates that the hippocampus is involved in various cognitive domains (Cohen et al., 1997; Kumaran & Maguire, 2005). This mechanism has been characterized as the function of rapidly, continuously, and obligatorily forming associations among disparate elements across space and time and further enabling the comparison of internal representations with current perceptual input (Olsen et al., 2012).

It is important to note that a series of events has structure beyond a sequence of chunks based on a timeline (Richmond & Zacks, 2017). When experience unfolds over time, interrelated stimuli or information across overlapping experiences are processed and bound together to form a coherent memory (Eichenbaum & Cohen, 2004). In this sense, the hippocampus supports a narrative-level organization of events that is not only dependent on the semantic information of single words and sentences alone but also on the connection between them. For example, a recurring B item in separated A-B and B-C pairs may trigger the association between temporally distant experiences, which is supported by the hippocampus. Additionally, new events can trigger the hippocampus to reinstate the activity pattern corresponding to a prior, overlapping event, thereby embedding information from the prior events into memory for the new event (Horner et al., 2015). In other words, the hippocampus integrates temporally separated events in memory during the process of constructing narratives. This process enhances the retrieval of the details of the events (Cohn-Sheehy et al., 2021). It has also been proposed that the hippocampus integrates events into a narrative only at a specific moment, the event boundary (Baldassano et al., 2017; Sinclair et al., 2021).

## 2.4 The Boundary Effect: Mapping Onto the Context

The hippocampus is particularly active when people perceive transitions between events (Zacks, 2020) and retrieval across event boundaries (Swallow et al., 2011). Event boundaries are usually introduced by the changes in time, space, and characters involved in the corresponding event. It has been proposed that the hippocampus has two distinct functions. One is within-event, which binds disparate features of an event into a coherent representation. The other occurs at the event boundary. Boundaries produce large contextual shifts, setting the stage for linguistic reference. Event boundaries can take many forms, including temporal boundaries (DuBrow & Davachi, 2013, 2016; Ezzyat & Davachi, 2011), spatial boundaries (Horner et al., 2016), and goal-related boundaries (Speer et al., 2007; Zacks et al., 2001). Importantly, all these forms of boundaries exert influence over episodic memory (Griffiths & Fuentemilla, 2020). I suggest that these forms of boundaries can also be mapped onto the event representation proposed by Davidson (1967). The hippocampus's phasic response at event boundaries has been proposed to implement a "now print" function that enhances later retrieval. In addition to retrieval, it has also been proposed that this activity predicts subsequent episodes (Ben-Yakov & Dudai, 2011; Ben-Yakov et al., 2013) or constructs a new event (Griffiths & Fuentemilla, 2020). The boundary effect then functions as a bridge that connects an event that has happened and an event that will happen.

Through the lens of event boundaries and the phasic activity of the hippocampus, we highlight the constructive nature of the hippocampus mechanism. Event boundaries not only contribute to the later retrieval of memory but also project related information about the event onto the context and our first-person experience, which can guide future

thinking and further stabilize online communication. I propose that this function of the hippocampus at the event boundary forms a solid foundation for human-unique reference which is equipped with a linguistic format. In the following section, I will briefly review how linguistic theory formulates the connection between narrow syntax and the conceptual-intentional system (semantics).

### 3. Linguistic Theory – A Minimalist View of Language

Our faculty of language (FL) is one of the biological components of our brain and the most accessible part of the mind. It serves as a window into how we can understand the relationship between language and episodic memory. Simply speaking, language is organized into two components: the lexicon (a collection of lexical items) and narrow syntax (the computational system that connects words). With these two components, our experiences can be packed into objects and events, which can be further assembled into propositions. FL could function as a cognitive zoom lens, enabling us to articulate the intricate details of an activity, such as *eating an apple*, or to broaden our perspective to encompass the entire event, like *I ate an apple*. We can distinguish between the past, present, and future. Events based on this mental timeline can be conceived as “time stuff”: Similar to objects, they may exist in a punctate or extended form, possess boundaries, gradually fade away, and be comprised of a singular occurrence or a collection of repetitions (Pinker, 2003).

The essential development of event semantics can be traced back to Davidson (1967), but when considering how linguistic theories could enable us to understand the nature of events that occur along the timeline, it is necessary to mention the fundamental fact about the combinatorial power of narrow syntax—the infinite use of finite means. An infinite number of sentences can be generated by a finite number of rule systems. This infinite use of finite means is achieved through Merge, the most fundamental operation within Minimalism (Chomsky, 1995).

Merge is assumed to serve as the only generative engine of human language. Minimalism is understood as an attempt to ‘reconstruct syntactic theory around Merge as the central computational operation’ (Jackendoff, 2011). By definition, Merge takes two syntactic objects and combines them into a set.

- (1) Merge  
Select two lexical items  $\alpha$  and  $\beta$  and form the set  $\{\alpha, \beta\}$ :  
 $M(\alpha, \beta) = \{\alpha, \beta\}$

When two lexical items (LIs) are merged, one of them emerges as the dominant element and is projected as the head:  $M(\alpha, \beta) = \{\alpha\{\alpha, \beta\}\}$  or  $\{\beta\{\alpha, \beta\}\}$ . With the verb phrase ‘eat



beef', the label is eat since this word determines the category of the phrase (a verb phrase, not noun phrase). The symmetric process of combining elements requires an asymmetric act of projection, resulting in an asymmetric relationship between the head and its complement.

Minimalism seeks to investigate whether the properties of FL could be understood by guidelines of computational efficiency and interface conditions (see Boeckx & Uriagereka 2007). Accordingly, minimalism could be viewed as a 'strong thesis' concerning the design of FL which states that language communicates with external systems of human biology optimally.

- (2) Strongest Minimalist Thesis (SMT)  
Language is an optimal solution to legibility conditions.  
(from Chomsky, 2000, p. 96)

In this sense, the result of the operation of Merge is regulated by the external requirements of the conceptual-intentional (semantic) and sensorimotor (sound/sign) systems, the interfaces between narrow syntax and the external systems. The SMT allows us to seriously consider whether the linguistic phenomenon could meet the general biological restrictions. Researchers also propose that narrow syntax is able to combine information from various modules (core knowledge systems) through which connections across modular boundaries can be carried out (Boeckx, 2010; Carruthers, 2002, 2006; Spelke, 2003). Within the current version of generative grammar, Phase theory was proposed to capture the process of how that core linguistic computational system interacts with other cognitive systems.

### 3.1 Phase Theory

Phase theory was introduced in the late nineties (Chomsky, 2000), and defines a phase as the minimal computational domain in syntax. Further, syntactic derivations are divided into 'chunks' sent to the conceptual-intentional (semantic) and sensorimotor (sound/sign) systems cyclically (Gallego, 2010).

Phases consist of a designated component, the phase-head, which is assumed to be the locus of various features that enter into Agree/Minimal Search, and its complement, termed the 'complement domain', which is assumed to be transferred to the interfaces for interpretation (Chomsky, 2001). Everything apart from the complement domain of the phase (i.e., the phase-head, as well as the specifiers and adjoined material above it) constitutes the edge domain.

From a derivational perspective, a rhythmic alternation between phase-edges and phase-complements is generated along with the syntactic derivation. As a result of the Minimal Search operation, phase-heads such as *v* or *C* (which are contained in the phase-edges) will label the whole syntactic object, i.e. *vP* or *CP*, headed by them in the

set  $\{v, VP\}$  and  $\{C, TP\}$ . An inherently asymmetrical arrangement of phase edges and phase complements forms the main spine of syntactic trees. The rhythmic pattern is illustrated in (3).

- (3) {Phase edge, {Phase complement, Phase edge, {Phase complement, Phase edge, {Phase complement}}}}

In Chomsky (2004, 2008) and associated research, CP and vP are identified as phases, whereas TP is not. In addition, noun phrases, particularly complete DPs are assumed to be phases (Chomsky, 2007). The DP phase represents the concept of ‘object’. The vP possesses a complete argument structure and can be mapped onto ‘event’. CP is the context-sensitive domain that can be mapped onto the notion ‘proposition’.

On the one hand, phase theory captures the core properties of derivational dynamics in syntax. On the other hand, phases reduce the computational complexity (Boeckx, 2014). Phase theory follows the tradition that computational dynamics are governed by some deep and systemic periodicity. Accordingly, the computational efficiency and properties of the systems with which FL interacts should be considered. This view has been consistent in Chomsky’s (2000, 2001, 2004, 2005, 2008) works.

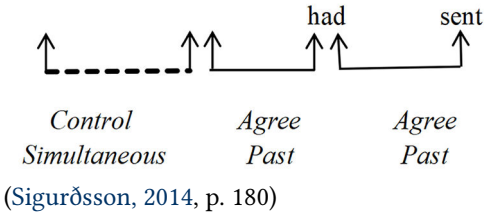
### 3.2 Phase Boundary Effect

‘Phase boundary’ in this section refers to the derivational boundary between each phase (vp, CP and DP). A phase boundary appears when full computation of the phase is completed. ‘Phase boundary effect’ refers to the phenomenon that when the connections between phases are established, the references of the contentful elements are fixed onto the context. It has been assumed that the phase edge serves an essential role at the boundary, the point where complements of the phases are transferred to CI/SM for interpretation. The phase edge implements the transition between phases and mediates the connection between phase-internal categories and the context of the phase. In (4), I adopted the simplified template of Phase in Hinzen and Sheehan (2013), because this template can be better mapped onto the event structure in episodic memory in a more intuitive manner. TP is assumed to contain grammatical categories, like Tense and Aspect, in the mainstream Minimalist Program (MP) model. Since this information is already included in the event structure expressed through vP, TP is not illustrated in (4). Propositions, events and objects are asymmetrically ordered with respect to one another, with propositions always (or architecturally) containing events as part of their structure, forming their thematic core, and events in turn containing objects.

- (4) [<sub>Edge</sub> [<sub>C</sub> proposition [<sub>Edge</sub> [<sub>v</sub> event [<sub>Edge</sub> [<sub>D</sub> object]]]]]  
(Hinzen & Sheehan, 2013)

Sigurðsson (2011, 2014) proposed that every type of phase is equipped with a silent linking Edge Feature. This feature not only facilitates the connection between phases, but also allows narrow syntax to establish connections with context, which refers to the deictic speech act context and/or the linguistic context (either in superordinate syntactic structures or in preceding discourse) (Sigurðsson, 2014, p. 176) and broad syntax, which is mainly related to the discourse features located in the C-domain, for example Force, Top(ic), and Foc(us). In order to illustrate how tense is mapped onto the context, Sigurðsson (2014) provides the following analysis:

(5) Now [CP... T<sub>S</sub>... [TP... T<sub>R</sub>... [vP... T<sub>E</sub>... ]]]



In (5), Agree is a narrow syntax operation, while Control is assumed to identify the relationship between phases and their context. Agree relations in the sentence ‘Edward had sent the letter’ are valued between the event time of reading, T<sub>E</sub>, the reference time of the past tense form *had*, T<sub>R</sub>, and the speech time, T<sub>S</sub>, which is simultaneously under the control of “speaker now”. T<sub>E</sub>, T<sub>R</sub> and T<sub>S</sub> are assumed to be the edge elements. The interaction between these two processes yields the full interpretation at the interfaces.

In a series of works by Hinzen and colleagues, ‘grammatical relations’ are highlighted in their phase-based framework, which lacks a status in the mainstream MP model. Hinzen and Sheehan (2013) propose that it is the grammatical organization that provides the distinctive character of human propositional thought. Accordingly, the grammatical computation of the phase gives rise to our ability to refer and predicate, the result of which is propositional truth. Accordingly, the edge in Hinzen’s framework houses grammatical elements that govern reference of the phase.

In addition to the analyses that focus on syntax, another account of event structure based on phase theory suggests that the source of this information is grounded in extra-linguistic cognition but not purely derived from grammatical organization (Ramchand & Svenonius, 2014). By focusing on the analysis of the verbal domain, Ramchand and colleagues suggest that there are underlying cognitive biases that serve as the cognitive backdrop for syntax and could lead to certain syntactic structures that can be universally detected. Such biases are independent of syntax but could give rise to ‘the separation of percepts into domains (e.g. events, which have participants, versus objects, which can be participants in events) or the organization of perceived states of affairs in terms of

Figure and Ground' (Ramchand & Svenonius, 2014, p. 161; see Murphy, 2015, for related discussion).

Following this line, I would like to highlight the essential position of the hippocampus in the interaction between episodic memory and the narrow syntax of language. Based on the cyclic activity of the hippocampus in event processing and the hippocampal function in semantic and referential processing (Piai et al., 2016), I propose that the interaction between episodic memory and narrow syntax gives rise to the interpretation of event representation. Narrow syntax provides a format for episodic memory to be expressed. The interaction between the two domains proceeds in a phase-based manner and the functions of the linguistic phase edge at each stage of the derivation (CP, vP and DP) can be mapped onto the functions of the hippocampus at the boundary of its phasic activity.

From a theoretical perspective, this section briefly reviews linguistic minimalism, phase theory, and how the phase boundary relates to the interpretation of linguistic items. Linguists have different views on the phase boundary and the source of interpretation. These differences have a direct impact on how we understand mental disorders with language-related problems, such as Alzheimer's disease. Whether these problems are purely linguistic or derived from the interface between the narrow syntax of language and episodic memory directly relates to the etiology of this pathology.

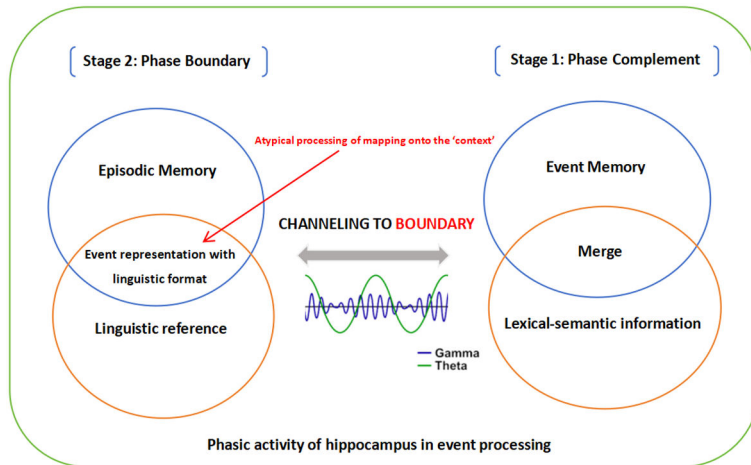
## 4 Language-Episodic Memory Interface Model

Previous studies suggest that the hippocampus supports the flexibility of online language communication (Duff & Brown-Schmidt, 2012). I suggest that the flexibility we observe in language and episodic memory is due to the dynamic interaction between the phase complement, where elements of the event are combined through constructional principles, the narrow syntax, and the phase edge, where a representation of the event can be mapped onto the context. The dynamic interaction between narrow syntax and episodic memory is presented in Figure 1. Phase complement here does not imply the head-complement structural relation that is normally used to describe the linguistic phenomenon. Rather, it only indicates that the elements that are combined at the first stage are subject to the mapping process at the boundary.

Event memory and episodic memory are different in the sense that episodic memory is located in subjective time (Nyberg et al., 2010), self-referential (Rubin & Umanath, 2015), and conscious in nature (Dew & Cabeza, 2011), while event memory lacks these dimensions. Thus, the latter is referred to as a mental construction of a scene that doesn't necessarily require reliving specific events. At stage one, event memory and language are assumed to share the constructive operation. For example, imagine an event in the mind: 'I BUY DOG'. We have the ability to construct this event, even though we have not experienced it before. In linguistics, the concepts of 'I', 'BUY' and 'DOG' must be

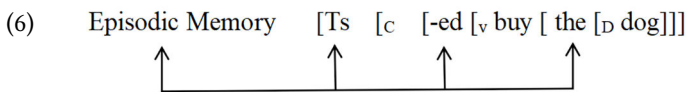
**Figure 1**

*A Schematic View of the Interface Between the Narrow Syntax of Language and Episodic Memory*



*Note.* Merge = the operation of narrow syntax which is assumed to be shared between event memory and language. The information about an event (*who*, *where* and *when*) in the event memory and the corresponding lexical-semantic information in language are combined to form an event representation in the first stage of the hippocampal activity. Event representation with linguistic format = the event representation formed in the first stage of hippocampal activity can be assigned the correct linguistic format if and only if the event representation can be matched with the corresponding information in the episodic memory. The results of this give rise to the linguistic function of reference, which has a truth value. Theta-gamma coupling = brain oscillation that bridges the hippocampal function from Stage 1 to Stage 2.

lexicalized first to enter the combinatorics. At stage two, the event ‘I BUY DOG’ is mapped onto the event representation in the episodic memory to get valued. If true, the corresponding linguistic format can be further assigned based on event representation in episodic memory. Imagine that the event ‘I BUY DOG’ happened two days ago, and there is a specific dog that I want to buy. The relationship between episodic memory and linguistic representation could then be illustrated in (6).



I suggest that at every stage of the derivation of the event representation, to be more specific, at each boundary, the lexicalized concept is registered in episodic memory. This is realized through the linguistic element at the edge. For example, the definite article ‘the’ that appears at the edge of DP ‘the dog’ can refer to the specific dog in the episodic

memory. Similarly, the past tense marker ‘-ed’ is used to express the action ‘buy’ that has happened and is stored in the episodic memory. In the C domain, the propositional claim, which could have a truth value, is generated. Or, as Sigurðsson (2014) proposed, the feature related to speech time is under the simultaneous control of the ‘speaker now’. As a result, we obtain a reference specific to the event in our episodic memory.

As for the shared operation proposed at stage one, it has been shown that a common scene construction mechanism is used in both recalling an event that has happened and imagining something that could happen in the future (Hassabis & Maguire, 2007; Szpunar et al., 2009). The resulting representation is complete with spatial-temporal context. As Richmond and Zacks (2017) suggested, this shared mechanism is crucial for ongoing comprehension, retrieval, and imaging, since they both capture spatial-temporal contexts, persons, entities, and objects and combine them into a structured representation. The constructive nature of this mechanism can be directly linked to the communicative function of episodic memory: providing grounds for believing (Mahr & Csibra, 2018). In linguistic terms, this relates to how the truth value can be assigned to a proposition that has a referential meaning. And this forms the basis of effective online communication. The intersection illustrated at the phase boundary in Figure 1 represents how episodic memory contributes to this kind of meaning. In sum, both domains are indexical and generative in nature, and their collaboration paves the way for real-time language communication. I propose that the boundary effects in linguistics can be projected onto the boundary effects in the hippocampus.

I suggest that phase boundary effects in both linguistics and episodic memory can be captured by the properties of hippocampal oscillations, and the term phase in both domains is more than just a superficial similarity in terminology. We suggest that they reflect the underlying rhythm of the general principles of physical organization (Kaku, 1995). As one of the reviewers noted, the conceptual contents of the two domains are distinct and need further study to provide a solid bridging theory. In this paper, we would like to suggest that brain oscillation could be one of the possible bridges that connect these two domains. In this sense, we attempt to expand on Murphy (2021)’s insight on how brain oscillation could implement elementary linguistic operations. To be more specific, we would like to focus on the functions of theta (~4–8Hz), gamma (~30–150Hz) and the theta-gamma coupling in the following paragraph.

The hippocampus serves as the site of theta-gamma coupling, through which a single theta wave can embed several gamma waves (Bragin et al., 1995). Pu et al. (2020) have suggested that theta oscillation is not only implicated in memory and navigation but also in linguistic processing. However, the authors still have questions about the specific roles hippocampal theta oscillations may play in language and how they can be connected with episodic memory. While Benítez-Burraco and Murphy (2019) predict that hippocampal theta indexes specifically lexico-semantic processing, I suggest that theta marks the edge part of the phase, where narrow syntax and episodic memory

interface. As for the theta-gamma phase-amplitude coupling, evidence suggests that it provides a neural code for recording sequences (Lisman & Jensen, 2013). Each gamma cycle in this framework is thought to relate to the firing of a cell population that codes a unique element in the sequence. In other words, gamma assigns an index to the element, which can be further processed and associated with an information-rich representation (Teyler & Rudy, 2007). In this sense, theta oscillation organizes these gamma cycles into a sequence. It has been proposed that theta-gamma coupling not only serves as a method to link together elements but also serves as a mechanism to maintain the duration of these elements in the event (Axmacher et al., 2010). It has also been suggested that the number of lexical features able to be transferred in a given derivational cycle could be constrained by this process. Further, it could also be a related mechanism for combining linguistic features (Murphy, 2021, 2024). In this sense, the operation at stage one could map onto this process.

During the interaction between stage one and stage two, lexico-semantic elements are valued at the edge for further processing in episodic memory and to be assigned a referential meaning. Such interaction is also reminiscent of the functions of the hippocampus, such as pattern separation and pattern completion. The interaction between pattern separation and pattern completion is assumed to be optimal for memory integration (Griffiths & Fuentesmilla, 2020). Whether we can detect a pattern in the context and complete it depends on how we can map the representation that is generated within the phase. The model in this section aims to capture the generic formal operations at this level of abstraction which forms the basis for both the narrow syntax of language and episodic memory. Hence, this model serves as an attempt to face 'Poeppel's challenge' and tries to answer the granularity problem encountered in the literature of cognitive science (Poeppel & Embick, 2005).

Our model predicts that whenever there is a problem with episodic memory, the linguistic reference will be impaired to some degree. These questions are assumed to occur at the phase boundary, where the narrow syntax of language and episodic memory interface. Our model also provides a practical direction for many previous studies that report linguistic problems in cases of cognitive impairment. The linguistic problems caused by cognitive impairment are not necessarily grammatical problems in nature, and we should re-examine various disorders from the perspective of the interface between the narrow syntax of language and episodic memory. Although this hypothesis has yet to be subjected to direct experimental testing, there is supporting evidence in cognitive disorders.

## 5 Neurological Evidence

Alzheimer's disease (AD) is a neurodegenerative disorder that causes one of the most common types of memory loss and other cognitive malfunctions (Maccioni et al., 2001).

The hippocampus is one of the essential brain regions involved in AD (Sperling et al., 2010). Due to the accumulation of amyloid-beta plaques and tau tangles, the hippocampus undergoes significant atrophy in individuals with AD (John & Reddy, 2021). Accordingly, progressive impairment in episodic memory (Tromp et al., 2015), spatial navigation abilities (Hort et al., 2007), language (Klimova et al., 2015) and overall cognitive malfunctioning occur (Jacobs et al., 1994). What is relevant to our hypothesis is that a recent study found that AD patients and healthy controls showed significant differences in the linguistic variables relating to the specificity of referencing of objects and events (Chapin et al., 2022). Hence, it confirms our hypothesis on the close relationship between episodic memory and the narrow syntax of language.

Williams syndrome (WS) is a rare genetic disorder marked by both physical and cognitive impairments (Morris & Mervis, 2000). One of the notable characteristics of WS is an abnormal development of the hippocampus. Studies have shown that individuals with WS exhibit reduced volume and altered structure of the hippocampus, which can contribute to their learning difficulties and impaired spatial processing skills (Meyer-Lindenberg et al., 2005). Research has shown that individuals with WS exhibit deficits in episodic memory, such as recalling autobiographical events and contextual details (Souhay et al., 2013), which are directly related to the malfunction of the hippocampus. Furthermore, research has identified a connection between these memory deficiencies and other cognitive functions like language comprehension and social cognition in individuals with WS (Martens et al., 2008). Individuals with WS typically display significantly delayed language development during early childhood. Their language is characterized by grammatical errors, a limited vocabulary, and unusual prosody (Brock, 2007). In a recent ERP study, Soberats (2023) found that in adults with WS, referential anchoring is impaired while lexical semantics is preserved.

In sum, the referential problems found in individuals with WS and AD can be linked to atypical processing of the hippocampal activity at the boundary. It is not surprising that when one's concept of time and place becomes blurred and confusing, language cannot capture them and express them properly in online communication. In this section, only two examples are provided, but I believe that there will be more cases that can prove our hypothesis.

## 6 Future Direction

While the hypothesis offers a new model for understanding the interconnectedness of episodic memory and the narrow syntax of language, it is essential to recognize potential counterexamples that may refute this hypothesis. One such counterexample lies in the existence of individuals with selective impairments in either episodic memory or language, despite the intact functioning of the hippocampus. For instance, patients with semantic dementia, a neurodegenerative disorder affecting semantic memory, may exhib-



it deficits in language comprehension and production without significant impairment in episodic memory. Similarly, individuals with specific language impairments, such as aphasia following a stroke, may experience profound language difficulties while retaining intact episodic memory abilities. These instances suggest that the relationship between episodic memory and language may not solely rely on hippocampal function but may involve additional neural substrates and networks. Moreover, research employing neuroimaging techniques has revealed dissociable patterns of brain activation associated with episodic memory and linguistic tasks, indicating that distinct neural circuits may underlie these cognitive functions. Furthermore, the role of the hippocampus in episodic memory may extend beyond its involvement in language processing, encompassing other cognitive processes such as spatial navigation and contextual memory. As for the issues related to brain oscillation, there is still no clear answer as to whether disturbed theta-gamma coupling is directly related to the symptoms in AD and WS. Thus, it is essential to consider these problems and design experiments that target both the narrow syntax of language and episodic memory in the future.

## 7 Concluding Remarks

From a theoretical perspective, this article explores the relationship between episodic memory and the narrow syntax of language. I suggest that the similarity in using the term ‘phase’ to capture the properties of the phenomenon in both domains is not merely a coincidence but can be treated as a window for us to explore the shared computational mechanism. The main point of this article relates to one of the primary functions of episodic memory: communication (Mahr & Csibra, 2018). On the one hand, the referentiality of event representation cannot be fulfilled without episodic memory. On the other hand, only when episodic memory is given a linguistic format can the event representation in the episodic memory be shared socially. Both language and episodic memory are broad terms and involve various cognitive processes. In a brief article, it's challenging to fully elucidate every detail about these cognitive processes. Our intention is to raise awareness among linguists that exploring episodic memory and the narrow syntax of language within the framework of interconnected cognitive functions may yield more fruitful insights.

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**Funding:** The author has no funding to report.

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**Acknowledgments:** The author has no additional (i.e., non-financial) support to report.

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**Competing Interests:** The author has declared that no competing interests exist.

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## References

- Allen, T. A., & Fortin, N. J. (2013). The evolution of episodic memory. *Proceedings of the National Academy of Sciences of the United States of America*, *110*, 10379–10386. <https://doi.org/10.1073/pnas.1301199110>
- Axmacher, N., Henseler, M. M., Jensen, O., Weinreich, I., Elger, C. E., & Fell, J. (2010). Cross-frequency coupling supports multi-item working memory in the human hippocampus. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(7), 3228–3233. <https://doi.org/10.1073/pnas.0911531107>
- Baldassano, C., Chen, J., Zadbood, A., Pillow, J. W., Hasson, U., & Norman, K. A. (2017). Discovering event structure in continuous narrative perception and memory. *Neuron*, *95*(3), 709–721.e5. <https://doi.org/10.1016/j.neuron.2017.06.041>
- Benítez-Burraco, A., & Murphy, E. (2019). Why brain oscillations are improving our understanding of language. *Frontiers in Behavioral Neuroscience*, *13*, Article 190. <https://doi.org/10.3389/fnbeh.2019.00190>
- Ben-Yakov, A., & Dudai, Y. (2011). Constructing realistic engrams: Poststimulus activity of hippocampus and dorsal striatum predicts subsequent episodic memory. *The Journal of Neuroscience*, *31*(24), 9032–9042. <https://doi.org/10.1523/JNEUROSCI.0702-11.2011>
- Ben-Yakov, A., Eshel, N., & Dudai, Y. (2013). Hippocampal immediate poststimulus activity in the encoding of consecutive naturalistic episodes. *Journal of Experimental Psychology: General*, *142*(4), 1255–1263. <https://doi.org/10.1037/a0033558>
- Boeckx, C. (2010). *Language in cognition: Uncovering mental structures and the rules behind them*. Wiley Blackwell.
- Boeckx, C. (2014). *Elementary syntactic structures: Prospects of a feature-free syntax* (Vol. 144). Cambridge University Press. <https://doi.org/10.1017/CBO9781139524391>
- Boeckx, C., & Uriagereka, J. (2007). Minimalism. In G. Ramchand & C. Reiss (Eds.), *The Oxford handbook of linguistic interfaces* (pp. 541–573). Oxford University Press.
- Bragin, A., Jando, G., Nádasdy, Z., Hetke, J., Wise, K., & Buzsáki, G. (1995). Gamma (40–100 Hz) oscillation in the hippocampus of the behaving rat. *The Journal of Neuroscience*, *15*(1), 47–60. <https://doi.org/10.1523/JNEUROSCI.15-01-00047.1995>
- Brock, J. (2007). Language abilities in Williams syndrome: A critical review. *Development and Psychopathology*, *19*(1), 97–127. <https://doi.org/10.1017/S095457940707006X>
- Buckner, R. L., & Carroll, D. C. (2007). Self-projection and the brain. *Trends in Cognitive Sciences*, *11*(2), 49–57. <https://doi.org/10.1016/j.tics.2006.11.004>
- Campbell, K. L., & Tyler, L. K. (2018). Language-related domain-specific and domain-general systems in the human brain. *Current Opinion in Behavioral Sciences*, *21*, 132–137. <https://doi.org/10.1016/j.cobeha.2018.04.008>
- Carruthers, P. (2002). The cognitive functions of language. *Behavioral and Brain Sciences*, *25*, 657–726. <https://doi.org/10.1017/S0140525X02000122>
- Carruthers, P. (2006). *The architecture of the mind: massive modularity and the flexibility of thought*. Oxford University Press.

- Chapin, K., Clarke, N., Garrard, P., & Hinzen, W. (2022). A finer-grained linguistic profile of Alzheimer's disease and Mild Cognitive Impairment. *Journal of Neurolinguistics*, 63, Article 101069. <https://doi.org/10.1016/j.jneuroling.2022.101069>
- Chomsky, N. (1995). *The minimalist program*. MIT Press.
- Chomsky, N. (2000). *New horizons in the study of language and mind*. Cambridge University Press.
- Chomsky, N. (2001). Derivation by phase. In M. Kenstowicz (Ed.), *Ken Hale: A life in language* (pp. 1–52). The MIT Press.
- Chomsky, N. (2004). Beyond explanatory adequacy. In A. Belletti (Ed.), *Structures and beyond: The cartography of syntactic structures* (Vol. 3, pp. 104–131). University Press.
- Chomsky, N. (2005). Three factors in language design. *Linguistic Inquiry*, 36(1), 1–22. <https://doi.org/10.1162/0024389052993655>
- Chomsky, N. (2007). Approaching UG from below. In U. Sauerland & H.-M. Gärtner (Eds.), *Interfaces + Recursion = Language? Chomsky's minimalism and the view from syntax-semantics* (pp. 1–30). Mouton de Gruyter.
- Chomsky, N. (2008). On phases. In R. Freidin, C. P. Otero & M. L. Zubizarreta (Eds.), *Foundational issues in linguistic theory: Essays in honor of Jean-Roger Vergnaud* (pp. 134–166). The MIT Press.
- Cohen, N. J., Poldrack, R. A., & Eichenbaum, H. (1997). Memory for items and memory for relations in the procedural/declarative memory framework. *Memory*, 5(1-2), 131–178. <https://doi.org/10.1080/741941149>
- Cohn-Sheehy, B. I., Delarazan, A. I., Reagh, Z. M., Crivelli-Decker, J. E., Kim, K., Barnett, A. J., Zacks, J. M., & Ranganath, C. (2021). The hippocampus constructs narrative memories across distant events. *Current Biology*, 31(22), 4935–4945.e7. <https://doi.org/10.1016/j.cub.2021.09.013>
- Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review*, 107(2), 261–288. <https://doi.org/10.1037/0033-295X.107.2.261>
- Corballis, M. C. (2019). Language, memory, and mental time travel: An evolutionary perspective. *Frontiers in Human Neuroscience*, 13, Article 455779. <https://doi.org/10.3389/fnhum.2019.00217>
- Corballis, M. C., & Suddendorf, T. (2007). Memory, time and language. In C. Pasternak (Ed.), *What makes us human* (pp. 17–36). Oneworld.
- Cowell, R. A., Barense, M. D., & Sadil, P. S. (2019). A roadmap for understanding memory: Decomposing cognitive processes into operations and representations. *eNeuro*, 6(4), Article ENEURO.0122-19.2019. <https://doi.org/10.1523/ENEURO.0122-19.2019>
- Davidson, D. (1967). The logical form of action sentences. In D. Davidson (Ed.), *Essays on actions and event* (pp. 105–148). Clarendon Press.
- Dew, I. T., & Cabeza, R. (2011). The porous boundaries between explicit and implicit memory: Behavioral and neural evidence. *Annals of the New York Academy of Sciences*, 1224(1), 174–190. <https://doi.org/10.1111/j.1749-6632.2010.05946.x>
- Dokic, J. (2001). Is memory purely preservative? In C. Hoerl & T. McCormack (Eds.), *Time and memory: Issues in philosophy and psychology* (pp. 213–232). Oxford University Press.

- DuBrow, S., & Davachi, L. (2013). The influence of context boundaries on memory for the sequential order of events. *Journal of Experimental Psychology. General*, *142*(4), 1277–1286.
- DuBrow, S., & Davachi, L. (2016). Temporal binding within and across events. *Neurobiology of Learning and Memory*, *134*, 107–114. <https://doi.org/10.1016/j.nlm.2016.07.011>
- Duff, M. C., & Brown-Schmidt, S. (2012). The hippocampus and the flexible use and processing of language. *Frontiers in Human Neuroscience*, *6*, Article 69. <https://doi.org/10.3389/fnhum.2012.00069>
- Duff, M. C., Covington, N. V., Hilverman, C., & Cohen, N. J. (2020). Semantic memory and the hippocampus: Revisiting, reaffirming, and extending the reach of their critical relationship. *Frontiers in Human Neuroscience*, *13*, Article 471. <https://doi.org/10.3389/fnhum.2019.00471>
- Eichenbaum, H., & Cohen, N. J. (2004). *From conditioning to conscious recollection: Memory systems of the brain* (No. 35). Oxford University Press.
- Ezzyat, Y., & Davachi, L. (2011). What constitutes an episode in episodic memory? *Psychological Science*, *22*(2), 243–252. <https://doi.org/10.1177/0956797610393742>
- Gallego, Á. J. (2010). *Phase theory*. John Benjamins.
- Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *11*(3), 501–518. <https://doi.org/10.1037/0278-7393.11.3.501>
- Griffiths, B. J., & Fuentemilla, L. (2020). Event conjunction: How the hippocampus integrates episodic memories across event boundaries. *Hippocampus*, *30*(2), 162–171. <https://doi.org/10.1002/hipo.23161>
- Hamamé, C. M., Alario, F. X., Llorens, A., Liégeois-Chauvel, C., & Trébuchon-Da Fonseca, A. (2014). High frequency gamma activity in the left hippocampus predicts visual object naming performance. *Brain and Language*, *135*, 104–114. <https://doi.org/10.1016/j.bandl.2014.05.007>
- Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in Cognitive Sciences*, *11*(7), 299–306. <https://doi.org/10.1016/j.tics.2007.05.001>
- Hassabis, D., & Maguire, E. A. (2009). The construction system of the brain. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *364*(1521), 1263–1271. <https://doi.org/10.1098/rstb.2008.0296>
- Hinzen, W. (2014). What is un-Cartesian linguistics? *Biolinguistics*, *8*, 226–257. <https://doi.org/10.5964/bioling.8999>
- Hinzen, W., & Sheehan, M. (2013). *The philosophy of universal grammar*. Oxford University Press.
- Horner, A. J., Bisby, J. A., Bush, D., Lin, W. J., & Burgess, N. (2015). Evidence for holistic episodic recollection via hippocampal pattern completion. *Nature Communications*, *6*(1), Article 7462. <https://doi.org/10.1038/ncomms8462>
- Horner, A. J., Bisby, J. A., Wang, A., Bogus, K., & Burgess, N. (2016). The role of spatial boundaries in shaping long-term event representations. *Cognition*, *154*, 151–164. <https://doi.org/10.1016/j.cognition.2016.05.013>

- Hort, J., Laczó, J., Vyhňálek, M., Bojar, M., Bureš, J., & Vlček, K. (2007). Spatial navigation deficit in amnesic mild cognitive impairment. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(10), 4042–4047. <https://doi.org/10.1073/pnas.0611314104>
- Jackendoff, R. (2011). What is the human language faculty? Two views. *Language*, *87*(3), 586–624. <https://doi.org/10.1353/lan.2011.0063>
- Jacobs, D., Sano, M., Marder, K., Bell, K., Bylsma, F., Lafleche, G., Albert, M., Brandt, J., & Stern, Y. (1994). Age at onset of Alzheimer's disease: Relation to pattern of cognitive dysfunction and rate of decline. *Neurology*, *44*(7), 1215–1220. <https://doi.org/10.1212/WNL.44.7.1215>
- Jin, W., Qin, H., Zhang, K., & Chen, X. (2020). Spatial navigation. In H. Wang (Ed.), *Neural circuits of innate behaviors* (pp. 63–90). [https://doi.org/10.1007/978-981-15-7086-5\\_7](https://doi.org/10.1007/978-981-15-7086-5_7)
- John, A., & Reddy, P. H. (2021). Synaptic basis of Alzheimer's disease: Focus on synaptic amyloid beta, P-tau and mitochondria. *Ageing Research Reviews*, *65*, Article 101208. <https://doi.org/10.1016/j.arr.2020.101208>
- Kaku, M. (1995). *Hyperspace: A scientific odyssey through parallel universes, time warps, and the tenth dimension*. OUP Oxford.
- Klein, S. B., German, T. P., Cosmides, L., & Gabriel, R. (2004). A theory of autobiographical memory: Necessary components and disorders resulting from their loss. *Social Cognition*, *22*(5), 460–490. <https://doi.org/10.1521/soco.22.5.460.50765>
- Klimova, B., Maresova, P., Valis, M., Hort, J., & Kuca, K. (2015). Alzheimer's disease and language impairments: Social intervention and medical treatment. *Clinical Interventions in Aging*, *2015*(10), 1401–1408. <https://doi.org/10.2147/CIA.S89714>
- Lisman, J. E., & Jensen, O. (2013). The theta-gamma neural code. *Neuron*, *77*(6), 1002–1016. <https://doi.org/10.1016/j.neuron.2013.03.007>
- Maccioni, R. B., Muñoz, J. P., & Barbeito, L. (2001). The molecular bases of Alzheimer's disease and other neurodegenerative disorders. *Archives of Medical Research*, *32*(5), 367–381. [https://doi.org/10.1016/S0188-4409\(01\)00316-2](https://doi.org/10.1016/S0188-4409(01)00316-2)
- Mahr, J. B., & Csibra, G. (2018). Why do we remember? The communicative function of episodic memory. *Behavioral and Brain Sciences*, *41*, Article e1. <https://doi.org/10.1017/S0140525X17000012>
- Martens, M. A., Wilson, S. J., & Reutens, D. C. (2008). Research Review: Williams syndrome: A critical review of the cognitive, behavioral, and neuroanatomical phenotype. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *49*(6), 576–608. <https://doi.org/10.1111/j.1469-7610.2008.01887.x>
- Meyer-Lindenberg, A., Mervis, C. B., Sarpal, D., Koch, P., Steele, S., Kohn, P., Marengo, S., Morris, C. A., Das, S., Kippenhan, S., & Mattay, V. S. (2005). Functional, structural, and metabolic abnormalities of the hippocampal formation in Williams syndrome. *The Journal of Clinical Investigation*, *115*(7), 1888–1895. <https://doi.org/10.1172/JCI24892>
- Morris, C. A., & Mervis, C. B. (2000). Williams syndrome and related disorders. *Annual Review of Genomics and Human Genetics*, *1*(1), 461–484. <https://doi.org/10.1146/annurev.genom.1.1.461>

- Murphy, E. (2015). Reference, phases and individuation: Topics at the labeling-interpretive interface. *Opticon*, 1826(17), 1–13. <https://doi.org/10.5334/opt.cn>
- Murphy, E. (2021). *The oscillatory nature of language*. Cambridge University Press.
- Murphy, E. (2024). ROSE: A neurocomputational architecture for syntax. *Journal of Neurolinguistics*, 70, Article 101180. <https://doi.org/10.1016/j.jneuroling.2023.101180>
- Murphy, E., Hoshi, K., & Benítez-Burraco, A. (2022). Subcortical syntax: Reconsidering the neural dynamics of language. *Journal of Neurolinguistics*, 62, Article 101062. <https://doi.org/10.1016/j.jneuroling.2022.101062>
- Neisser, U. (2008). Memory with a grain of salt. In H. H. Wood & A. S. Byatt (Eds.), *Memory: An anthology* (pp. 80–88). Chatto & Windus.
- Nyberg, L., Kim, A. S., Habib, R., Levine, B., & Tulving, E. (2010). Consciousness of subjective time in the brain. *Proceedings of the National Academy of Sciences of the United States of America*, 107(51), 22356–22359. <https://doi.org/10.1073/pnas.1016823108>
- Olsen, R. K., Moses, S. N., Riggs, L., & Ryan, J. D. (2012). The hippocampus supports multiple cognitive processes through relational binding and comparison. *Frontiers in Human Neuroscience*, 6, Article 146. <https://doi.org/10.3389/fnhum.2012.00146>
- Opitz, B., & Friederici, A. D. (2003). Interactions of the hippocampal system and the prefrontal cortex in learning language-like rules. *NeuroImage*, 19(4), 1730–1737. [https://doi.org/10.1016/S1053-8119\(03\)00170-8](https://doi.org/10.1016/S1053-8119(03)00170-8)
- Park, S. E., Lee, J., & Lee, S. A. (2023). Domain-general and domain-specific electrophysiological markers of cognitive distance coding for what, where, and when memory retrieval. *The Journal of Neuroscience*, 43(23), 4304–4314. <https://doi.org/10.1523/JNEUROSCI.0261-23.2023>
- Piai, V., Anderson, K. L., Lin, J. J., Dewar, C., Parvizi, J., Dronkers, N. F., & Knight, R. T. (2016). Direct brain recordings reveal hippocampal rhythm underpinnings of language processing. *Proceedings of the National Academy of Sciences*, 113(40), 11366–11371. <https://doi.org/10.1073/pnas.1603312113>
- Pinker, S. (2003). *The language instinct: How the mind creates language*. Penguin.
- Poeppel, D., & Embick, D. (2005). Defining the relation between linguistics and neuroscience. In A. Cutler (Ed.), *Twenty-first century psycholinguistics: Four cornerstones* (pp. 173–189). Erlbaum.
- Poldrack, R. A., & Packard, M. G. (2003). Competition among multiple memory systems: Converging evidence from animal and human brain studies. *Neuropsychologia*, 41(3), 245–251. [https://doi.org/10.1016/S0028-3932\(02\)00157-4](https://doi.org/10.1016/S0028-3932(02)00157-4)
- Pu, Y., Cheyne, D., Sun, Y., & Johnson, B. W. (2020). Theta oscillations support the interface between language and memory. *NeuroImage*, 215, Article 116782. <https://doi.org/10.1016/j.neuroimage.2020.116782>
- Ramchand, G., & Svenonius, P. (2014). Deriving the functional hierarchy. *Language Sciences*, 46, 152–174. <https://doi.org/10.1016/j.langsci.2014.06.013>
- Richmond, L. L., & Zacks, J. M. (2017). Constructing experience: Event models from perception to action. *Trends in Cognitive Sciences*, 21(12), 962–980. <https://doi.org/10.1016/j.tics.2017.08.005>

- Rubin, D. C., & Umanath, S. (2015). Event memory: A theory of memory for laboratory, autobiographical, and fictional events. *Psychological Review*, *122*(1), 1–23. <https://doi.org/10.1037/a0037907>
- Schacter, D. L., & Tulving, E. (1994). *Memory systems*. MIT Press.
- Sigurðsson, H. Á. (2011). Conditions on argument drop. *Linguistic Inquiry*, *42*(2), 267–304. [https://doi.org/10.1162/LING\\_a\\_00042](https://doi.org/10.1162/LING_a_00042)
- Sigurðsson, H. Á. (2014). Context-linked grammar. *Language Sciences*, *46*, 175–188. <https://doi.org/10.1016/j.langsci.2014.06.010>
- Sinclair, A. H., Manalili, G. M., Brunec, I. K., Adcock, R. A., & Barense, M. D. (2021). Prediction errors disrupt hippocampal representations and update episodic memories. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(51), Article e2117625118. <https://doi.org/10.1073/pnas.2117625118>
- Soberats, C. (2023). *Processing of sentential meaning: Behavioural and electroencephalographic evidence in neurotypical and Williams syndrome adult populations* [Doctoral thesis]. Pompeu Fabra University.
- Souchay, C., Guillery-Girard, B., Pauly-Takacs, K., Wojcik, D. Z., & Eustache, F. (2013). Subjective experience of episodic memory and metacognition: A neurodevelopmental approach. *Frontiers in Behavioral Neuroscience*, *7*, Article 212. <https://doi.org/10.3389/fnbeh.2013.00212>
- Speer, N. K., Zacks, J. M., & Reynolds, J. R. (2007). Human brain activity time-locked to narrative event boundaries. *Psychological Science*, *18*(5), 449–455. <https://doi.org/10.1111/j.1467-9280.2007.01920.x>
- Spelke, E. S. (2003). What makes us smart? Core knowledge and natural language. In D. Gentner & S. Goldin-Meadow (Eds.), *Language in mind: Advances in the investigation of language and thought* (pp. 277–311). MIT Press.
- Sperling, R. A., Dickerson, B. C., Pihlajamaki, M., Vannini, P., LaViolette, P. S., Vitolo, O. V., Hedden, T., Becker, J. A., Rentz, D. M., Selkoe, D. J., & Johnson, K. A. (2010). Functional alterations in memory networks in early Alzheimer's disease. *Neuromolecular Medicine*, *12*, 27–43. <https://doi.org/10.1007/s12017-009-8109-7>
- Swallow, K. M., Barch, D. M., Head, D., Maley, C. J., Holder, D., & Zacks, J. M. (2011). Changes in events alter how people remember recent information. *Journal of Cognitive Neuroscience*, *23*(5), 1052–1064. <https://doi.org/10.1162/jocn.2010.21524>
- Szpunar, K. K., Chan, J. C., & McDermott, K. B. (2009). Contextual processing in episodic future thought. *Cerebral Cortex*, *19*(7), 1539–1548. <https://doi.org/10.1093/cercor/bhn191>
- Takashima, A., Bakker, I., Van Hell, J. G., Janzen, G., & McQueen, J. M. (2014). Richness of information about novel words influences how episodic and semantic memory networks interact during lexicalization. *NeuroImage*, *84*, 265–278. <https://doi.org/10.1016/j.neuroimage.2013.08.023>
- Taylor, T. J., & Rudy, J. W. (2007). The hippocampal indexing theory and episodic memory: Updating the index. *Hippocampus*, *17*(12), 1158–1169. <https://doi.org/10.1002/hipo.20350>

- Tromp, D., Dufour, A., Lithfous, S., Pebayle, T., & Després, O. (2015). Episodic memory in normal aging and Alzheimer disease: Insights from imaging and behavioral studies. *Ageing Research Reviews*, 24, 232–262. <https://doi.org/10.1016/j.arr.2015.08.006>
- Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory* (pp. 381–403), Academic Press.
- Tulving, E. (1983). *Elements of episodic memory*. Clarendon.
- Tulving, E. (1985). Memory and consciousness. *Canadian Psychology*, 26(1), 1–12. <https://doi.org/10.1037/h0080017>
- Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, 53(1), 1–25. <https://doi.org/10.1146/annurev.psych.53.100901.135114>
- Tulving, E., & Markowitsch, H. J. (1998). Episodic and declarative memory: Role of the hippocampus. *Hippocampus*, 8(3), 198–204. [https://doi.org/10.1002/\(SICI\)1098-1063\(1998\)8:3<198::AID-HIPO2>3.0.CO;2-G](https://doi.org/10.1002/(SICI)1098-1063(1998)8:3<198::AID-HIPO2>3.0.CO;2-G)
- Kinsbourne, M., & Wood, F. (1975). Short-term memory processes and the amnesic syndrome. In D. Deutsch & J. A. Deutsch (Eds.), *Short-term memory* (pp. 258–291). Academic Press.
- Kumaran, D., & Maguire, E. A. (2005). The human hippocampus: Cognitive maps or relational memory? *The Journal of Neuroscience*, 25(31), 7254–7259. <https://doi.org/10.1523/JNEUROSCI.1103-05.2005>
- Ullman, M. T. (2001a). The declarative/procedural model of lexicon and grammar. *Journal of Psycholinguistic Research*, 30(1), 37–69. <https://doi.org/10.1023/A:1005204207369>
- Ullman, M. T. (2001b). A neurocognitive perspective on language: The declarative/procedural model. *Nature Reviews. Neuroscience*, 2, 717–726. <https://doi.org/10.1038/35094573>
- Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition*, 92(1-2), 231–270. <https://doi.org/10.1016/j.cognition.2003.10.008>
- Ullman, M. T. (2016). The declarative/procedural model: A neurobiological model of language learning, knowledge, and use. In G. Hickok & S. L. Small (Eds.), *Neurobiology of language* (pp. 953–968). Elsevier.
- Wang, Y., & Gennari, S. P. (2019). How language and event recall can shape memory for time. *Cognitive Psychology*, 108, 1–21. <https://doi.org/10.1016/j.cogpsych.2018.10.003>
- Wiltgen, B. J., Zhou, M., Cai, Y., Balaji, J., Karlsson, M. G., Parivash, S. N., Li, W., & Silva, A. J. (2010). The hippocampus plays a selective role in the retrieval of detailed contextual memories. *Current Biology*, 20(15), 1336–1344. <https://doi.org/10.1016/j.cub.2010.06.068>
- Zaccarella, E., & Friederici, A. D. (2015). Merge in the human brain: A sub-region based functional investigation in the left pars opercularis. *Frontiers in Psychology*, 6, Article 1818. <https://doi.org/10.3389/fpsyg.2015.01818>
- Zacks, J. M. (2020). Event perception and memory. *Annual Review of Psychology*, 71, 165–191. <https://doi.org/10.1146/annurev-psych-010419-051101>
- Zacks, J. M., Braver, T. S., Sheridan, M. A., Donaldson, D. I., Snyder, A. Z., Ollinger, J. M., Buckner, R. L., & Raichle, M. E. (2001). Human brain activity time-locked to perceptual event boundaries. *Nature Neuroscience*, 4(6), 651–655. <https://doi.org/10.1038/88486>