Taxonomy and Unity of Memory

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To appear in:
Bernecker, S. & Michaelian, K. (Eds., 2017). *Routledge Handbook of Philosophy of Memory*.
London: Routledge.

1. Introductory linguistic considerations

In the most general way of speaking, people use the noun "memory" to refer to instances where information of the past is made available for present purposes. In this minimal sense the rings of trees are memories of the climatic conditions in the seasonal succession of years during certain periods of the past. The characteristic features of tree rings make available this information for the present purposes of dendrologists. Likewise hieroglyphs inside the Cheops pyramid make information about political events in the lifetime of pharaoh Cheops available to egyptologists and can justly be called memories of that time. Making available information of the past for present purposes is also the function of certain psychological states of humans and animals that we refer to by the noun "memory". For the psychological domain, in English, we also have the verb "remember" along with the verbs "recall" and "recollect" (as well as less frequently used or more remotely related verbs like "reminisce", "memorize", "commemorate", "think of"). The usages of the three verbs differ slightly, but – at least, most of the time – refer to instances of memory. Syntactically speaking, the verb "remember" alone can figure in a great variety of grammatical constructions taking noun phrases and that-clauses or interrogative (wh-)clauses as well as infinitival and gerundival constructions as dependent arguments:

(1) At his wife's funeral the widower vividly remembered their wedding.
(2) The teacher remembers his best pupil well.
(3) John remembers his first car whenever he visits his parents.
(4) The dog remembered his way home.
(5) The history student remembered that Napoleon was exiled in Elba.
(6) The client remembered her PIN number.
(7) The math professor remembered that 311 is a prime number.
(8) The tourist remembered where Cicero besieged Vercingetorix and visited the place.
(9) Remember to send in your application by the end of the week!
(10) The victim remembered hiding in the basement.
(11) The waitress remembered the burglar carrying a gun.
(12) At the front door the woman remembers that her latchkey is still in the car.
(13) The football coach remembers that the tournament will take place on Labor Day.
(14) Standing in front of the locked entrance door, the customer remembered that the bank closes at 2 o'clock every Friday.
(15) In the English language tutorial the student remembered that "feline" means cat.

(16) After the stroke the patient did not remember how to ride a bike.

Semantically speaking, there seems to be little restriction on the argument of “remember”: If it is a noun phrase, it can refer to an event (as in 1 and 10), a person (2, 11), a concrete object (3) or an abstract object (4, 6). The argument may also denote a complete proposition (5, 7, 12, 13, 14, 15; also 9 with the infinitival construction resulting from syntactic raising) or an incomplete proposition (8; also 16). The proposition often pertains to a particular event or object in the past (5, 8), but can also be about something particular in the present (12) or future (13). However, the proposition need not target a concrete particular at all, but may have a general (14) or abstract (7, 15) content. How-to-constructions (16), it has been argued, have a least one reading where “remember” refers to a procedural capacity without an intentional content fully accessible to the subject.

In some cases the intentional object of the mental state denoted by “remember” was directly experienced by the subject and may even be part of his/her autobiography (as in 1), In other cases (as e.g. in 5 and 8) it was not directly experienced and the memory is indirect. In some case there might be no relation to a particular experience at all (as e.g. in 7). It is, however, widely agreed that “remember” comes with a presupposition of the factivity of the intentional object that the state referred to by “remember” is directed to. That is, the existence of the object or person in question, the occurrence of the event, or the truth of the proposition is presupposed when the embedding sentence is asserted. Whether the presupposition of factivity is regarded more as a matter of pragmatics than one of semantics depends, a.o., on whether one is ready to allow for its subsequent cancellation. The more you are inclined to regard the following discourse as outright contradictory, the more you are in favor of the stronger semantic rather than the softer pragmatic view:

(17) The waitress remembered that the burglar carried a gun. In fact, he carried only a knife.

Making a presupposition of factivity, the verb “remember” aligns with verbs like “regret”, “accept” and “forget”. Assertions of

(18) The coach remembered/regretted/accepted/forgot that Bayern Munich lost against Manchester United.

all presuppose that Munich indeed lost against Manchester. It is a characteristic feature of presuppositions as opposed to (semantic) entailments or (pragmatic) implicatures that they are upheld in negated contexts. Assertions of

(19) The coach did not remember/regret/accept/forget that Bayern Munich lost against Manchester United.

also (normally) presuppose the truth of the that-clause. What exactly underlies presuppositions, how widespread they are, under which conditions they can be cancelled and whether they are a matter of pragmatics or semantics is an ongoing debate in linguistics (Sauerland & Stateva, 2007, ed.).

Many philosophers have appealed to grammatical features of the verb "remember" to make categorical distinctions in the domain of memory. One, for instance, quite frequently finds authors who base their distinction between episodic and semantic memory on the grammatical distinction between the gerundival (20, 22) and the that-clause constructions (21, 23):

(20) The victim remembered hiding in the basement.
(21) The victim remembered that he hid in the basement.
(22) The waitress remembered the burglar carrying a gun.
(23) The waitress remembered that the burglar carried a gun.

However, this grammatical variation seems to be rather particular to English and not at all universal. In a language as closely akin as German the gerundival construction does not exist (or is strongly marked) and all cases have to go with the that(*dass*)-clause construction. It seems questionable if anything at all can justly be inferred for the categorization of memories from a grammatical variation that one language offers and another does not.

Other authors (e.g., Bernecker, 2010) have proposed to distinguish between propositional and non-propositional memories depending on whether the psychological state in question is denoted by the verb "remember" taking a that-clause or taking a noun phrase as argument. Compare

(24) John remembers that his wife was wearing a blue hat at their wedding.
(25) John remembers the blue hat his wife was wearing at their wedding.
(26) John remembers his wife wearing a blue hat at their wedding.

According to this proposal the mental state referred to in (24) should belong to the category of propositional memories and (25) to the category of non-propositional memories. However, to which of the two categories does (26) belong? Grammatically, the gerundival construction is a noun phrase. It should therefore count as non-propositional memory. Semantically, though, (26) has (exactly or nearly) the same truth-conditions as (24). How could the mental state denoted in (26) then be categorially different (if at all different) from the state of propositional memory denoted in (24)? Liefke and Werning (2016, in revision) indeed argue that the fact that certain verbs allow for both that-clauses and noun phrases as arguments does not license the (type-theoretic) inference that the verb itself is polysemous. In the light of these problems, basing a taxonomy of memory on grammatical consideration does not seem favorable to us.

We will, therefore, now turn to non-linguistic approaches towards taxonomizing memories. In the literature a variety of taxonomies with different taxonomical maxims have been offered. In this chapter we will systematize and evaluate the most prominent taxonomical approaches towards memory along their general structure by distinguishing scalar, hierarchical and natural-kind based taxonomies. Scalar taxonomy divides up the various types of memories along a linear scale: the time span of memory. Hierarchical taxonomy follows the Aristotelian method of *definitio per* *genus proximum et differentia specifica.* This approach has mainly been applied to cases of long-term memories. Here, memories are first categorized into declarative and non-declarative memories. In a second step the category of declarative memories is further subdivided into semantic and episodic memories. For this hierarchy of categories content-based, phenomenological and merely descriptive criteria have been proposed. Natural-kind based taxonomies, in contrast, try to identify a category with a maximal class whose members are likely to share a set of properties for relevant inductive and explanatory purposes because of some underlying uniform causal mechanism. So far this approach has been developed in a promising way, as we argue, for episodic memory. We think that it is less promising for other cases of memories.

2. Scalar Taxonomy

We would like to begin with as broad a view on memory as possible to provide a context for the narrower memory phenomena that we will discuss later in this chapter. Initially, we will discuss phenomena that the uninitiated might not think of as memory, but would fit under the minimal definition given in the beginning of this chapter. Atkinson and Shiffrin (1968) proposed that human memory could be divided into three classes depending on their persistence in time: ultra-short-term memory, short-term memory, and long-term memory. However, even though these three types of memory are identified according to their duration, they in fact differ in several other aspects, as well, that together suggest that they are qualitatively different types of memory.

Ultra-short-term memory, or sensory memory, makes sensory information that does not exist anymore in the physical world available for processing for less than 1 second (Coltheart, 1980). This kind of memory is specific to a particular sensory system and does not appear to be shared across sensory systems. In the visual system ultra-short-term memory is the reason, why, for example, we perceive apparent, continuous motion when watching a movie instead of 25 individual frames per second. To perceive apparent motion, our visual system has to store at least one previous frame and compare it to the current frame. The offset of an object in two consecutive images is then interpreted by our perceptual system as motion. Atkinson and Shiffrin suggested that ultra-short-term memory is limited to only a few hundred milliseconds in duration because the memory traces decay naturally. The timescale is so short that we are not aware of it as a form of memory. We also cannot consciously control ultra-short-term memory since it is entirely driven by external stimuli. For these reasons, some researchers suggest alternatively that ultra-short-term memory is a component of the sensory system rather than a memory system.

Short-term memory can be used to store information for up to 30 seconds (Cowan, 2008). It is filled with sensory information without a conscious effort, such as when we are remembering the beginning of a long sentence while listening to a speaker to make sense of the sentence. However, short-term memory is less dependent on sensory inputs than ultra-short-term memory and can be controlled consciously. For instance, we can make a mental shopping list for our groceries while driving on the highway. Most importantly, through covert rehearsal we can prevent the spontaneous decay of short-term memories and therefore sustain them for more than the 30 seconds, after which they would normally have decayed. For instance, we might hold on to our mental shopping list for minutes by covertly articulating the items repeated. Experimental studies have shown that short-term memory has a limited capacity, perhaps only 4 chunks (Cowan, 2001), although the exact capacity remains contentious. Even though the capacity may appear low, working memory can store more information than this number suggests, because several items can be combined into a single chunk, e.g., remembering a phone number in three chunks of numbers 234-322-7136 is much easier than remembering the string of 10 digits 2343227136.

Once memories enter the long-term memory store, they are no longer vulnerable to spontaneous decay and therefore could endure for a lifetime. Nonetheless, some memories may be forgotten due to interference from memories that are stored later. Other key differences to short-term memory are the larger, potentially unlimited, capacity and the storage of arbitrary combinations of different kinds of information in long-term memory. For instance, when we recall our last party, we might remember the names of participants, the images of their faces, the sound of their voices, the smell of their perfumes, and the feel of the host's sofa. Most importantly, we remember these things not in isolation, but including the context in which they are embedded and the relationship between them.

In addition to identifying the three different memory types, Atkinson and Shiffrin also suggested that they stand in a rather fixed relationship to one another. They proposed that stored information is processed sequentially entering the brain through the sensory system into ultra-short-term, pass through short-term memory and end up in long-term memory. This processing chain can, and frequently does, terminate when information is forgotten from one of the memory stores.

Over the years, several aspects of Atkinson and Shiffrin's taxonomy have been questioned. The main criticisms can be divided into two classes. First, their taxonomy artificially splits memories of the same kind into different taxa. Several authors have proposed that short-term memory and long-term memory are instances of the same unitary memory that happen to have different properties. Second, Atkinson and Shiffrin lump together disparate kinds of memories into a single taxon. This criticism concerns mostly long-term memory. Despite these controversies, Atkinson and Shiffrin's taxonomy has been and remains one of the most influential taxonomies of memory.

3. Hierarchical Taxonomy

While a scalar taxonomy is appealing due to its simplicity, a tremendous number of empirical studies in psychology and neuroscience have revealed that many instances of long-term memory appear quite distinct from one another. However, it remains highly controversial how to organize long-term memories into taxa. A frequently suggested approach is the hierarchical taxonomy according to Squire and Zola-Morgan (1988). In a first step, memory is split into declarative and non-declarative memory (Fig. 1). Memories of the former type are those that we can articulate, while we cannot articulate memories of the latter type. Sometimes these types of memory are also called explicit and implicit memory. The sentences (1) to (15) above give examples of declarative memory.

Examples of non-declarative memory include motor skills such as riding a bicycle. We are aware of our skill and can articulate at a superficial level how we perform those skills, e.g., “you sit on the saddle, put your feet on the pedals, hold on to the handle bar and peddle with your legs”. Anyone who has tried to teach a child to ride a bicycle can attest to the incompleteness of these instructions. What we are unable to describe are the multitudes of observations, computations and manipulations that we carry out while riding the bicycle, e.g., how we detect deviations and counteract them to keep the balance, how to predict whether we will collide with another rider who is on a collision course. Everyone who knows how to ride a bicycle has stored this information, and much more, since she can do the right thing when required to do so. That is why this type of memory is called motor *memory*. However, this information is not consciously accessible to us.

In a second step, two subordinate categories are introduced – first by Tulving (1972) – within the superordinate category of declarative memory, namely, semantic memory and episodic memory. Tulving conceived of semantic memory as general knowledge about oneself and the world and of episodic memory as memory of personally experienced events. At first glance, the distinction between episodic and semantic memory seems straight forward, but research in the subsequent decades revealed that this distinction is difficult to draw. Since this area of research is the most active and episodic memory is the closest to the everyday notion of memory, we will focus on episodic memory and its distinction from semantic memory in the following.

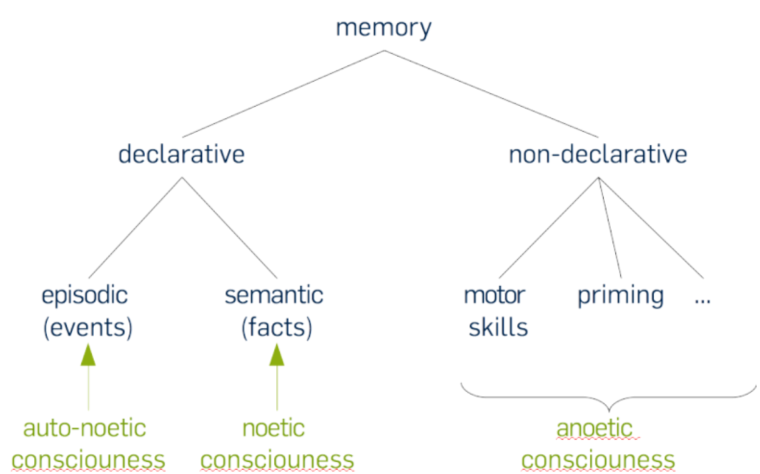

Figure 1: Hierarchical taxonomy of memory according to Squire and Zola-Morgan (1988) and its relationship to Tulving’s (1985) phenomenological taxonomy.

3.1. Content-based Taxonomy

Early differentiations between semantic and episodic memory were based on their content. When Tulving (1972) introduced the distinction between episodic and semantic memory, he suggested that episodic memories were unique in that they included information about the what-where-when of an event. Importantly, the three different types of information would have to be represented jointly in a single memory, not separately in different memories. Since the what-where-when criterion refers to the content of a memory that can be tested in non-human animals, it has been frequently employed in animal cognition studies. Memory of joint what-where-when information of an event has been reported in various avian and mammalian species.

While what-where-when information is undoubtedly frequently part of the content of episodic memory, the WWW criterion is insufficient to fully discern episodic from semantic memory. In some cases, the WWW criterion is too rigid. For instance, in episodic memories one of the WWW components can be poorly encoded or missing (Bauer et al., 2012; Friedman, 1993). In other cases, the WWW criterion is too liberal. For instance, semantic memory of an event that was not personally experienced may also contain all WWW components. To distinguish such semantic memories from episodic memories, Clayton et al. (2003) have suggested to add two more conditions, the structural and the flexibility condition. However, even with these additions Clayton et al. acknowledge that the combined criteria describe episodic-like memory, not proper episodic memory. In summary, even if the WWW criterion is convenient in nonhuman animal studies and supplemented by other conditions, it does not appear to appropriately capture the very idea of episodic memory in humans.

3.2. Phenomenological Taxonomy

Having realized the difficulty in distinguishing episodic from semantic memory on the basis of content alone, Tulving (1985) instead suggested a criterion based on the type of subjective experience during retrieval: anoetic, noetic and autonoetic consciousness. He suggested that non-declarative memory is associated with anoetic consciousness, meaning that we are aware of being capable of a certain skill, but not aware of the content of our memory of that skill. He further suggested that

> “[s]emantic memory is characterized by noetic consciousness. Noetic consciousness allows an organism to be aware of, and to cognitively operate on, objects and events, and relations among objects and events, in the absence of these objects and events. […]” (Tulving, 1985)

Finally, Tulving suggested that autonoetic consciousness was associated with episodic memory and enables the subject to be aware of having personally experienced the event. He likened the experience during retrieval of episodic memories to mental time travel into the past, a reliving of the past. However, the evolutionary purpose of traveling back in time can only be to inform future behavior. Suddendorf and Corballis (1997), therefore, suggested that the episodic memory system sustains mental time travel into the future. This suggestion is supported by experimental studies that show that amnesics have deficits in constructing imaginary scenes (Hassabis, Kumaran, Vann, & Maguire, 2007) and that the hippocampus is activated when healthy subjects imagine a future event (Weiler, Suchan, & Daum, 2010).

Suddendorf and Corballis made a strong argument that mental time travel is unique to humans. Although a number of animal cognition studies have sought to prove them wrong, Suddendorf and Corballis (2008), are not convinced because of methodological concerns and because the studied behaviors are limited to ecological niche behaviors, such as food-caching in scrub jays. Planning for the future in a narrow behavioral context, they argue, is not equivalent to mental time travel into the future.

Although Suddendorf and Corballis originally proposed the mental time travel idea to study foresight, it is arguably the currently most widely used account of episodic memory in humans. Despite its popularity, we believe that this approach is unsatisfactory at several levels. At a practical level, mental time travel is difficult, if not impossible, to study in nonhuman animals (Clayton et al., 2003) since it relies on the subjective experience during retrieval, which perhaps cannot be shared between different species. While it may turn out in the end that nonhuman animals do not possess episodic memory, that conclusion would be much stronger if episodic memory was not construed in such a way as to preclude, or severely bias against, this possibility. At a theoretical level, it seems unsatisfactory that the nature of a memory would depend predominantly on the subjective experience during recall since the memory persists even when not being recalled. One possible remedy might be to specify that a memory is episodic memory if an autonoetic recall could be cued (Klein, 2013). However, at a conceptual level, doubts are emerging about the association between different levels of consciousness and the retrieval of certain memories. For instance, it has been suggested that consciousness does not always accompany episodic memory retrieval (Hannula & Ranganath, 2009; Henke, 2010).

3.3. Descriptive Approaches

An alternative approach to explicating episodic memory is to list the properties of episodic memory and show that the sum of these properties distinguishes it from other forms of memory, in particular semantic memory. This approach, too, has been pioneered by Tulving who proposed that semantic memory differs from episodic memory in 28 properties (Tulving, 1983). For example, one contrast is: Episodic memories are memories of events or episodes that are organized temporally, whereas semantic memories are memories of facts, ideas, or concepts that are organized conceptually. This distinction is not as clear as it may seem at first glance since information about an event or episode that occurred is information about a fact, too. Some properties remain vague, such as the temporal organization of the information in episodic memory – a notion that plays a central role in our analysis below. Other properties are properties of the neural system supporting memory, rather than of individual memories, such as appearing early or late in development. It is conceivable that the sum of all 28 properties would clearly distinguish between semantic and episodic memory, but the descriptive approach faces two fundamental challenges. First, it is difficult to ascertain that the list of properties is complete. In other words, are all properties listed? Second, it remains unclear which properties are important characteristics of episodic memory and which ones are inconsequential. In other words, do all properties have to be on the list?

4. Natural-kind based taxonomy

It has recently become a central topic in the philosophy of psychology to ask whether certain notions used in psychology correspond to natural kinds and how this might assure that psychology has the inductive and explanatory potential we generally expect from sciences (Machery, 2009). The identification of natural kinds is neither the principal goal of the scalar and hierarchical taxonomies of memory, nor do these taxonomical approaches guarantee that the resulting classification reflects natural kinds. In the philosophy of science the dominant view of a natural kind is due to Boyd (1991) and commonly labelled "the homeostatic property cluster view". The core idea is that, in science, entities should be clustered together in a way that (i) optimizes the inductive and explanatory potential of theories that make reference to those clusters and (ii) that this inductive and explanatory potential should rest on uniform causal mechanisms underlying each cluster. In this spirit the notion of a natural kind can be defined as follows:

> A class C of entities is a natural kind if and only if there is a large set of properties that subserve relevant inductive and explanatory purposes such that C is the maximal class whose members are likely to share these properties because of some uniform causal mechanism.

The question whether memory, in general, is a natural kind has been addressed by Michaelian (2010) who argues for a negative answer. Furthermore, Bedford (1997) has argued that implicit memory is the result of a fallacy and should not be considered a category of memory. On the positive side, we have argued that episodic memory under a certain explication, indeed, is likely to be a natural kind (Cheng & Werning, 2016; Werning & Cheng, 2014). So far episodic memory, thus, is the only kind of memory for which an explicit case for it being a natural kind has been made.

In our approach the explication of episodic memory and its identification with a natural kind go hand in hand. The claim is that under a specific explication – the Sequence Analysis – and only under this explication, episodic memory constitutes a natural kind. The approach aims at a number of desiderata: (i) The explication needs to clarify what is potentially stored in episodic memory, that is, its content. (ii) Despite subjective experiences of recalling detailed episodic memories, numerous experimental studies have consistently found that episodic memory in humans often preserves little more than the gist of the experienced episode. Therefore, the explication has to integrate two competing requirements. On the one hand, the memory of an episode E must be allowed to differ in content (even significantly) from the experience of the grounding episode E^*. On the other hand, one has to enforce a sufficiently stringent relationship between the experiential base E^* and the mnemonic content E to justify that the memory is based in the experience. (iii) Even though overwhelming evidence indicates that subjects frequently retrieve inaccurate information when asked to recall episodic memories, these cases are regarded as improper episodic memory. The aim is an explication of memory that presupposes its factivity (see above).

The key to fulfilling these desiderata, we believe, is to emphasize the sequential nature of episodic memory. Sequentiality is a distinguishing structural feature of both the content of episodic memory and its underlying neural realization as had been suggested by various experimental studies and computation models (for review see: Cheng, 2013; Cheng & Werning, 2013; Hasselmo, 2012).

According to the Sequence Analysis a subject S has episodic memory with content E at a time t_1 if and only if the following conditions are fulfilled:

(S1) E is an episode with $E = \langle e_1, \ldots, e_n \rangle$ being a temporal sequence of events $e_1, \ldots, e_n$. E is called the *mnemonic content*.

(S2) At some time t_1, S compositionally[1] represents E as an episode of temporally succeeding events $e_1, \ldots, e_n$. S's representation of E at t_1 is called the *mnemonic representation*.

(S3) At a time $t_0 < t_1$, S has a reliable experience of the temporally succeeding events $e_1^*, \ldots, e_m^*$, which make up an episode $E^* = \langle e_1^*, \ldots, e_m^* \rangle$. E^* is called the *experiential base*.

(S4) The episode E^* occurs at or before t_0 (*factivity*).

(S5) The mnemonic content E is *ontologically grounded* in the experiential base E^* in the following sense of counterfactual dependence: Were E^* to occur at or before t_0, E would also occur at that time.

(S6) S's representation with content E at t_1 is *causally grounded* in S's experience of E^* through a reliable memory trace.

(S7) On the basis of its mnemonic representation with content E, S is capable of generating a temporally explicit simulation with content E at some time $t_2 \geq t_1$. The generated simulation is called a *mnemonic simulation*.

These conditions can be related to the four major stages of memory processing: perception, encoding, storage and retrieval. (S3) and (S4) propose conditions on perception, (S5) and (S6) on encoding, (S1) and (S2) on storage, and (S7) on retrieval.

According to the Sequence Analysis episodic memory is grounded in experience in a twofold way: with respect to content and to processing. With regard to content, the experienced

[1] Compositionality – the principle that the content of a complex representation is a structure-dependent function of the contents of its parts – is a widely acknowledged, though not uncontentious, criterion for the adequacy of representational structures in general, be they linguistic, conceptual or neural (Hodges, 2001; Werning, 2005; Werning, Hinzen, & Machery, 2012, ed.).

occurrence of the episode E^* secures the occurrence of the remembered episode E. What one has experienced, in other words, is a truth-maker of what one remembers. The ontological groundedness condition warrants a sufficiently strong, but not too strong dependence relation: It does not require the identity of the mnemonic content with the experiential base, but allows that the former be just a part or an abstraction of the latter, sometimes not more than its gist. With regard to processing, the state of memory is causally grounded in the state of experience through a reliable memory trace.

The Sequence Analysis does not content itself with the subject having a mnemonic representation, but demands that the subject be capable of generating a mnemonic simulation. In the mnemonic simulation the temporal succession of events in the domain of representational contents is represented itself by a temporal succession of events in the domain of the representational vehicles – in our case neural processes. This can be regarded a non-symbolic, emulative way of representation (Grush, 2004; Mroczko-Wąsowicz & Werning, 2012; Werning, 2012).

On the basis of empirical observations, it has been argued that the generative or constructive nature of the episodic memory system might be explained by postulating that information is added during retrieval (Bernecker, 2008; Michaelian, 2011; Schacter, 2012). Cheng, Werning and Suddendorf (2016) have argued that mnemonic simulation should be regarded as a result of scenario construction where (possibly rather sparse) episodic memory traces are enriched with semantic information. They discuss three options how one could potentially account, within this framework, for what Tulving (1985) called autonoetic consciousness: (i) *Meta-representation*: Autonoetic consciousness might simply consist in the presence of a meta-representation that one recalls the information about an episode as a result of one's own experience of that episode (Redshaw, 2014; Suddendorf, 1999). (ii) *Viewpoint-dependence*: Autonoetic consciousness might arise through the point of view a person assumes in the constructed scenario that includes the episode (Russell & Hanna, 2012). (iii) *Quasi-transparent simulation*: The phenomenal transparency of an experience (Harman, 1990; Moore, 1903), generally speaking, amounts to the property that having the experience of a scenario is for the experiencing subject just so (i.e. so and nothing in addition to it) as if the scenario were present (Werning, 2010). Even though experiencing a scenario during remembering is not as phenomenally transparent as a perception of the scenario would be, characterizations of remembering as "re-experiencing or reliving the past" suggest that autonoetic consciousness in certain respects resembles phenomenally transparent mental states.

Once the Sequence Analysis had been introduced as an explication of episodic memory, it was now possible to argue for the identification of episodic memory with a natural kind. This argumentation proceeded along three cornerstones. It was first demonstrated that the Sequence Analysis is both minimal and maximal with regard to its inductive and explanatory potential. Regarding the minimality, this means that any violation of one of the conditions corresponds to a deficiency in episodic memory. Examples for deficient cases of episodic memory are false memories and memories that are experientially ill-founded because there was no grounding experience or the experience was not reliable. Moreover, a deficiency might consist in the fact that the memory is not causally linked to the experience by a reliable memory trace – as e.g. is the case for retroactive inference due to imagination inflation or the misinformation effect (Marsh, Eslick, & Fazio, 2008) – or in the fact that the experiential base does not secure the mnemonic content – as in misattribution (Schacter & Dodson, 2001). A deficiency might also occur because the subject is unable to generate a mnemonic simulation at all as might be the case with repressed memories or because the subject generates a mnemonic simulation whose content does not match with that of the mnemonic representation, e.g., when suggestive questions bias the report of a subject's memory (Scoboria, Mazzoni, Kirsch, & Milling, 2002). Regarding the maximality, it was argued that other types of memories, most importantly semantic memories do not fulfill the conditions of the Sequence Analysis.

In a second step neuroanatomical and -physiological evidence was used to support the view that the principal anatomical substrate of episodic memory is the hippocampus. On the one hand, all processes hosted by the hippocampus contribute to episodic memory. On the other hand, even though episodic memory involves interactions with other cognitive processes, which are supported by a variety of brain regions, processes specific to episodic memory are hosted by the hippocampus.

In a final step, which can only be sketched here, it was argued that neural processes in the hippocampus provide uniform causal mechanisms for the processing stages proposed by the Sequence Analysis. Specific neural mechanism – viz. phase precession and theta sequences – indicate that the hippocampus provides a uniform causal mechanism that aligns the sequential representation of mnemonic content with the sequential representation of the experiential base. According to the Sequence Analysis, to form episodic memory in the hippocampus, a mnemonic representation of the episode E has to be stored in the hippocampus, where E has to be ontologically grounded in the experienced episode E^*. Many authors have suggested that the hippocampal circuitry is optimized for storing sequences. There is widespread agreement in neuroscience that mnemonic representations are stored in the weights of the synaptic connections between neurons. More specifically, it has been suggested that the dense recurrent network in a specific subarea of the hippocampus (CA3) is well suited to generate neural sequences (Azizi, Wiskott, & Cheng, 2013; Cheng, 2013; Levy, 1996; Lisman, 1999; Wallenstein, Eichenbaum, & Hasselmo, 1998). A specific compression mechanism – viz. theta phase precession (Dragoi & Buzsáki, 2006) – generates a representation of the experienced sequence of events at the shorter timescale required for synaptic plasticity. In the offline state, i.e. during retrieval, populations of neurons fire in a sequence that correlates with the sequence, in which they were active at an earlier time in the online state (Lee & Wilson, 2002). Thus, sequential neural activity in the offline state is a replay of sequential activity in prior experience. Interventions in the memory trace warrant that mnemonic representations are causally grounded in experiences as is evidenced by the disruption of systems consolidation. The claim that episodic memory as explicated by the

Sequence Analysis constitutes a natural kind with a uniform underlying neural mechanism could thus be corroborated.

5. Conclusions

We have begun our reflections on the unity and taxonomy of memory with the minimal notion of memory as something that makes information about the past available for present purposes. We have then seen that grammatical considerations about the verb "remember" might be valuable in itself, for the purposes of semanticists or for heuristic reasons, but are not conducive to an adequate taxonomization of the various psychological phenomena so denoted. For inductive and explanatory purposes sciences must have appropriate terminology to refer to the phenomena that they study. In recognition of this necessity, many taxonomies have been proposed in psychology and neuroscience. As, we have discussed in this chapter in regards to memory, these taxonomies are often based on a mixture of observations and intuitions about the most important aspects of the phenomena under consideration. However, these approaches tend to be *ad-hoc* and generally do not follow a principled agenda. We therefore propose that for the purposes of sciences such as psychology and neuroscience, identifying natural kinds would be the most fruitful approach where natural kinds should be taken as homeostatic property clusters. Uniform causal mechanisms explain why the psychological properties are shared such that the cluster of those properties subserves inductive and explanatory purposes.

As explicated by the Sequence Analysis, episodic memory is likely to be a natural kind. It remains an open question whether episodic memory is the only natural kind of memory. Klein (2014) appears to argue for this position and goes further by proposing that the term "memory" be used only to refer to episodic memory. His proposal would bring the scientific use of the word "memory" more in line with everyday language and ensure that memory, thus understood, is a natural kind. However, it might be premature, since the search for other natural kinds of memory is a fairly young endeavor, and suggestions of other natural kinds (Michaelian, 2010) among the memory phenomena should not be dismissed just yet.

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