**Memory Systems and the Mnemic Character of Procedural Memory**

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**Abstract**

According to a standard view in psychology and neuroscience, there are multiple memory systems in the brain. Philosophers and scientists of memory rely on the idea that there are multiple memory systems in the brain to infer that procedural memory is not a cognitive form of memory. As a result, memory is considered to be a disunified capacity. In this paper, I evaluate two criteria used by Michaelian to demarcate between cognitive and non-cognitive memory systems: appeal to stored content and retrieval flexibility. By considering several empirical cases I argue that the criteria offered ultimately fail to distinguish between memory systems. The procedural memory system is neither contentless nor inflexible.

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**1 Introduction**

One of the first things to notice when thinking about memory is the variety of forms it takes. We learn facts, re-live events, gain skills, and acquire habits. What exactly falls under the category of memory? The existence of various mnemic capacities raises questions about the way the sciences of memory should classify and delineate their objects of study. In cognitive neuroscience, a prominent way of capturing this variation is by the memory systems framework. In this framework, the mind can be divided into systems, each of which acquires a different kind of information.

According to the standard taxonomy, memory systems are divided into declarative and nondeclarative (or procedural) categories (Schacter and Tulving [1994]; Squire [2004]). Declarative memory supports recollection of facts and events while procedural memory allows for the formation of skills and habits. The presence of different memory systems has led scientists and philosophers to argue that procedural memory has a radically different characterization than declarative memory (Tulving [2000]; Klein [2015]; Werning and Cheng [2017]). Consequently, we should not expect to discover any general features of memory. In other words, memory is not a unitary capacity.

Michaelian ([2011]; [2015]; Michaelian and Sant’Anna [2019]), in particular, has argued that the evidential base supporting the memory systems framework may be used to infer that procedural memory is not a cognitive form of memory and serves to demarcate between cognitive and non-cognitive memory. Michaelian offers to distinguish procedural and declarative memory systems based on Marr’s three levels of description, thereby demonstrating that procedural and declarative memory do not share a common description. Michaelian argues that procedural memory is not a cognitive form of memory on the basis of two criteria: First, in the procedural memory system, there is no need to appeal to stored content to explain behaviour. Second, procedural and declarative memory systems differ substantially on the level of retrieval flexibility they provide.

In this paper, I will argue that Michaelian’s criteria mischaracterize the nature of procedural memory and show that memory systems do not lend themselves to such a disunified view. Specifically, I claim that the procedural memory system is neither contentless nor inflexible. By considering various examples which demonstrate that descriptions of the procedural memory system invoke stored content and substantial retrieval flexibility, I argue that the criteria offered by Michaelian do not apply to procedural memory. Moreover, not only is procedural memory not radically different from declarative memory, the existence of distinct memory systems does not undermine the plausibility of a unitary capacity.

Note that I focus only on the distinction between memory systems. My argument does not bear on the existence of memory systems. My focus is only on whether the data underlying the memory systems framework may serve as an evidential base from which to draw the lesson Michaelian draws from their existence. Consider also that while the conception of procedural memory as contentless and inflexible is widely endorsed in philosophy of memory, this conception has undergone substantial revisions in the science and philosophy of skill (Christensen et al. [2016]; Christensen et al. [2019]; De Brigard [2019]; Pavese [2019], [2020]; Fridland [2021]). There is, thus, a pressing need to reconsider the standard conception of memory systems.

I begin in section 2 by presenting the memory systems framework and the characterization of procedural memory it is believed to underwrite. In section 3 I consider Michaelian’s argument that only declarative memory is explained by appealing to stored content. I present the case of motor apraxia, a paradigmatic procedural memory deficit, as an example of appeals to stored content in the procedural memory system. In section 4 I present a second type of argument that draws on the behavioural flexibility associated with distinct memory systems. I then argue that declarative memory may exhibit inflexible forms of information processing while procedural memory may exhibit flexible forms of information processing. In section 5 I outline two ways to conceive how a unitary mnemic capacity might arise from multiple memory systems.

**2 Memory Systems**

There are various ways in which our past experiences affect us. Most straightforward, is the ability to experience the past. One could mentally re-experience past episodes such as one’s wedding. One can also recall facts divorced from any context, such as a mathematical theorem. A bit more controversially, one can also acquire memories very different from this sort of factual memories, such as skills and habits, remembering, for instance, how to ride a bike. Forms of learning such as associative conditioning are also grouped as mnemic capacities. All in all, it seems there is not much unity involved in memory.

A prominent approach to account for this diversity is to split the phenomenon into distinct forms of memory. The common practice in neuroscience follows such an approach, classifying various forms of memory into different systems. According to this approach, diﬀerent forms of memories result from the activity of memory systems, each with its own distinctive properties. These memory systems may operate independently from one another to support behaviour, and when a particular system malfunctions the form of memory associated with its operation will exhibit deficits.

A memory system, as initially characterized by Schacter and Tulving ([1994]), should satisfy the following criteria:

* A selective operation supporting tasks of an exclusive functional class
* A speciﬁc style of information processing
* A specific core neural structure

A form of memory satisfying these criteria may qualify as a memory system. Consider, for example, episodic memory. Its selective operation is, presumably, to encode events from one’s personal past (Tulving [2002]).[[1]](#footnote-1) It exhibits a speciﬁc style of information processing involving computation of cognitively ﬂexible representations (White and McDonald [2002]). The core neural area associated with this form of memory is the medial temporal lobe (Dickerson and Eichenbaum [2010]).[[2]](#footnote-2) According to the proposed criteria for memory systems, episodic memory qualifies as a memory system.

The idea that there are functionally distinct memory systems primarily results from a form of inference called double dissociation. The basic idea is, roughly, that functions could be localized and specified if brain lesions in a given area result in unimpaired performance on Task I but impaired performance on Task II, while different lesions in another area produce the reverse pattern: unimpaired performance on Task II but impaired performance on Task I. For instance, lesions to the hippocampus would result in impaired spatial learning but unimpaired habit learning, and lesions to the basal ganglia produce the opposite outcome. The inference resulting from this evidential pattern is the localization of a functional role such as spatial learning, to a specific brain area such as the hippocampus.

This form of inference is central to the memory systems framework (White et al. [2013]). The best explanation for this pattern of evidence has been interpreted to show that there are dissociable systems responsible for different memory functions (Craver [2004]; Davis [2010]). Memory is realized by distinct systems which can process informational relations independently. These distinct realizers are central brain areas that process specific input-output relations and are required in the acquisition of particular informational relations, acquisition that may not occur in the absence of these realizers.

The features of memory systems underlie taxonomies of memory. The standard taxonomy divides memory systems into two categories: declarative and nondeclarative (figure 1) (Squire [2004]).[[3]](#footnote-3) Declarative memory, which includes the episodic and semantic systems, is responsible for the capacity for conscious recollection about facts and events. Its name comes from the fact that memories processed by this system are verbally accessible. In most animals, where a linguistic report is unavailable, mnemic expression is treated as declarative when it involves a representation-based capacity such as cognitive maps. So, representations play an important role in explaining how this system processes information. Nondeclarative memory is an umbrella term encompassing various systems. Common to all of them, apparently, is that nondeclarative types of memory are expressed through performance rather than recollection, and attribution of representations to these systems is less straightforward, especially when considering the case of more reflex-like systems.[[4]](#footnote-4)

I focus specifically on the contrast between declarative and procedural memory systems, the memory system traditionally thought to support skilful and habitual behaviour through proceduralization of information into production rules (Anderson [1982]). The reason for focusing on procedural memory is that, although important for intelligent behaviour such as skills, its cognitive nature has been the subject of extensive debate (Sutton [2007]; Pavese [2019]).

**Figure 1.** A taxonomy of memory systems grouped into memory categories: declarative and nondeclarative (Squire [2004], p. 173)

**2.1 The characterization of procedural memory**

The idea that memory is not a unified category predates the memory systems framework, reflecting a common conception of the distinct ways in which past experience affects us (Danziger [2009]). Remembering a fact is so different from remembering a skill that it appears obvious that they represent distinct mental capacities. The memory systems characterized by neuroscience, and particularly the division between declarative and procedural memory, have repeatedly been cited in support of this intuitive understanding.

Two contrasting perspectives may be distinguished in the discussion over the nature of procedural memory. Some neuroscientists and philosophers infer from the evidence supporting the memory systems framework that procedural memory is wrongly classified as a mnemic capacity (Klein [2015]). Others have argued that procedural memory belongs to the core of memory itself, and that memory should be characterized sufficiently broad so that declarative and procedural forms could be accommodated (Schacter [2007]).

What is at stake between these different approaches to procedural memory? The crucial question is which inferences are allowed by our characterization of memory. Schacter ([2007]) proposes that memory, as a whole, can be characterized as a neurocognitive capacity to encode, store and retrieve information. This characterization, however, may be considered an inappropriate description of procedural memory. Indeed, one may naturally wonder what is exactly stored by gaining a habit. As Tulving has argued, expanding this characterization to incorporate procedural memory is ‘awkward at best and silly at worst’ ([2000], p. 38). While the cognitive role of storage and retrieval in declarative memory is widely acknowledged, the same cannot be said about procedural memory.

The issue at stake, therefore, is the cognitive character of memory. If we accept that procedural memory is a mnemic capacity we could end up conflating distinct phenomena, thereby misidentifying systems as cognitive in nature. In contrast, by denying that procedural memory is a mnemic capacity we could lose grip on the way the procedural memory system supports intelligent motor behaviour, thus ‘reinstating tired dichotomies between reason and the body’ (Sutton [2007], p. 772).

Michaelian is a notable proponent of the view that procedural and declarative memory are fundamentally different ([2011]; [2015]; Michaelian and Sant’Anna [2019]). Michaelian’s approach is especially relevant as it directly relies on the memory systems framework to reject procedural memory as a cognitive form of memory. According to Michaelian and Sant’Anna ‘since only declarative memory involves the construction of contentful representations [...] only declarative memory is really memory [...] the fundamental distinction is between declarative memory, on the one hand, and procedural memory, on the other hand’ ([2019], p. 23). Consequently, memory should not be considered a unitary capacity.

In the following sections, I consider two criteria that Michaelian uses to distinguish declarative from procedural memory based on memory systems. In the next section, I evaluate Michaelian’s argument, based on Marr’s three levels of description, that explanations of behaviour driven by the procedural memory system do not need to appeal to stored content. In section 4 I consider an alternative way in which Michaelian can establish a distinction between procedural and declarative memory by referring to the different forms of behavioural flexibility distinct memory systems support. By presenting several empirical cases I show that these criteria fail to establish that procedural memory is different in kind.

**3 A Common Description for Memory Systems**

To understand what memory systems are and how to distinguish between them, Michaelian proposes to use Marr’s tri-level analysis. According to Marr’s tri-level framework, we can understand a cognitive capacity through a distinction between computational, algorithmic, and implementational levels of description (Marr [1982]). Each level of description concerns a different aspect of a cognitive capacity that requires explanation (Bechtel and Shagrir [2015]). A complete explanation would involve all levels and thus one would expect that all instances of a given phenomenon would be given a similar tri-level description.

By using Marr’s levels of description to distinguish between memory systems, Michaelian asks whether memory systems can be similarly described along these levels of description. If memory systems do not share a similar description on any of these levels of description, then we may infer that they are not part of a more general kind of memory. If Memory systems do not process information in a similar way or they are not implemented in similar mechanisms, then these systems would qualify as distinct capacities.

In applying Marr’s levels of description, Michaelian argues, we see that declarative and procedural memory systems do not share any such similar description. Declarative memory systems tend to overlap anatomically, both depending on medial temporal lobe structures, while the procedural memory system is realized in a distinct anatomical base. On the algorithmic level, memory systems might be described by processes of encoding, storage, and retrieval, but appeal to stored information seems ill-suited in description of procedural memory, generally thought to involve associative conditioning and motor procedures. Finally, declarative and procedural memory systems are computationally different as only the former involves preservation of information representing past experience. Having no description in common across all levels supports the claim that procedural memory is radically different from declarative memory.

Michaelian relies on the diversity between memory systems to infer that ‘episodic and semantic memory but not procedural memory [count] as genuine forms of memory’ ([2015], p. 477). What underwrites the distinction between genuine and non-genuine memory? The crucial question about the procedural memory system concerns whether it could be described as encoding, storing, and retrieving information. A potential reply to this worry is that the procedural system involves encoding, storage, and retrieval of rule-based information.

Describing the procedural memory system as undergoing a process of encoding, storage, and retrieval, Michaelian argues, however, is explanatory redundant. Such a description is otiose: ‘a system need not represent the rules governing a learned behavior in order for its behavior to be governed by those rules’ ([2015], p.416). For reasons of simplicity, Michaelian says, there is no need for such description in the procedural system as ‘appeals to neural changes do all the work’ ([2016], p.179). Nothing of explanatory value is gained by referring to stored information in describing the procedural system.

To better understand Michaelian’s point about the explanatory redundancy of stored content in the procedural memory system, and his following rejection of describing it as engaging in encoding, storing, and retrieving information, consider the computational level. This level deals with the information processing task, specifically, with what the computation is aimed at. Comparing whether memory systems engage in similar information-processing tasks we find that declarative systems involve information that is not merely connected to past experiences but rather connects by preserving or matching past experience. Michaelian believes that appeal to stored information is explanatorily useful when it plays a role in describing how stored information guides behaviour. A substantial computational difference between declarative and procedural systems, then, has to do with the way stored information is made *available* to an organism.

Reference to stored information is required to explain forms of memory, such as episodic memory, because citing the content of past experience explains behaviour that results from having *access* to that information. For instance, I remember that I left the car lights running and suddenly leave the room. It is by citing the retrieved content that my behaviour is explained. In contrast, an explanation of how I remember to turn the car’s lights off as a result of a habit is exhausted by a description that does not require any notion of stored information. Only the former case requires referring to how stored information guided my behaviour. Hence, memory systems differ substantially on the computational level. Citing stored information is only needed to describe the information processing that declarative systems engage in.

As Michaelian suggests that memory systems should be classified according to computational similarity, the fact that an appeal to stored content is not explanatorily relevant to some systems shows that memory is not a unitary capacity. In Michaelian's view, memory systems are not sub kinds of a general kind because appealing to stored information is required in explaining only one type of systems - cognitive memory systems. So, to the extent that procedural memory is a mnemic capacity, it is not a cognitive capacity. Cognitive memory, as a unitary capacity, includes priming alongside more common systems such as episodic and semantic memory. Other systems are grouped under non-cognitive memory and Michaelian offers an alternative taxonomy to reflect this distinction.[[5]](#footnote-5)

**3.1 Apraxia and appeal to stored content**

Appealing to stored content in describing procedural memories, nevertheless, does sometimes play an explanatory role, and in some cases that role is indispensable. If an appeal to stored content does explanatory work in explaining memory that is related to procedural memory, then it shows that appeal to stored content is not exclusively relevant to cognitive memory systems. Reference to stored representations, however, undermines Michaelian’s distinction between cognitive and non-cognitive memory to the extent that it plays a similar role in cases of procedural memory. The appeal to stored content in the procedural memory system plays such a role in the case of motor apraxia.[[6]](#footnote-6)

Apraxia is a neuropsychological motor disorder characterized by the inability to correctly carry out a learned motor act despite the preserved capability of the motor system to produce the intended movement (Goldenberg [2013]). It is described as an impairment involving the procedural system, both physiologically, being associated with lesions to the basal ganglia, and behaviourally, considered to involve a deficit in learned motor procedures. The dissociation between the capacity to execute and the knowledge of how to execute a motor act points to the importance of stored representations in this type of syndrome. Specifically, apraxia is thought to involve the loss ofmotorrepresentations or the inability to adequately access representations of learned movements and motor skills in the damaged brain.

The importance of appeal to stored contents in characterizing this impairment can be seen by considering the different types in which apraxia is manifested (Heilman and Rothi [1993]). There are two types of apraxia, each involving a distinct kind of motor impairment. Ideomotor apraxia involves the loss of the ability to identify and discriminate gestures or skilled movements.[[7]](#footnote-7) Limb-kinetic apraxia is the inability to make ﬁne-grade and precise limb movements. Identifying which type of apraxia a patient suffers from requires determining which component of the motor system is impaired.

Evaluation involves asking a patient to carry out pantomime or demonstrate tool-use, to imitate a movement, and to discriminate between different and similar actions (Macauley and Handley [2005]; Negri et al. [2007]). Patients with ideomotor apraxia are able to imitate simple novel gestures utilizing their perceptual and motor systems but have more difﬁculty with reproducing complex gestures that, presumably, depend upon the activation of stored representations. On the other hand, patients who did not lose the relevant representations but suffer from limb-kinetic apraxia, cannot perform such gestures but are able to discriminate between actions. In the latter type of apraxia, patients are thought to suffer from a purely motor deficit (Jacobs et al. [1999]).

Analyzing the subjects’ ability to imitate and recognize gestures is needed to identify which type of dysfunction the patient has, and, subsequently, the type of treatment that should be given. Appeal to stored content in apraxia patients is used to distinguish between patients who are able to recognize learned gestures but cannot perform them, and those that can perform these gestures but cannot recognize them.[[8]](#footnote-8) Importantly, appealing to stored content is exactly what explains the distinction between forms of apraxia. Only by appealing to stored content may researchers perform this type of assessment.

Without being able to point to a loss of motor representations there would be no way to distinguish between apraxia involving loss of representations and apraxia that does not involve such loss. If citing stored representations was insignificant or would play no explanatory role, then the distinction between types of apraxia would be vacuous. Importantly, it is the availability of stored information that is referred to in making this distinction. So, appeal to stored content in the procedural memory system is not explanatorily inert. One cannot describe apraxia solely at the neural level, as part of the explanation relies on appealing to stored information.

One might think that action recognition or tool use are cognitive capacities and as such belong with other cognitive systems, perhaps involving processing by declarative memory regions such as the hippocampus. But that would be a mistake. Apraxia should not be considered a case of declarative memory as it is an impairment involving the procedural memory system. First, the impaired regions in apraxia are associated with procedural memory, and lesions to areas underlying this system result in loss of apraxia-related motor representations (Jacobs et al. [1999]). Damage to the hippocampus does not lead to these behavioural deficits. Second, apraxia patients are not representationally “damaged” across the board (Hayakawa et al. [2015]). The loss of representations occurs specifically in the motor domain.[[9]](#footnote-9) These patients cannot represent action kinematics, but they can recall autobiographical events and generally understand instructions.

A pressing concern might be that the role stored content plays in this case, and more generally, in procedural memory, is dissimilar to the one it has in declarative memory. For the case of motor apraxia to undermine Michaelian’s argument, the appeal to stored content should play a similar role to the one it has in cases of declarative memory. Specifically, appeal to stored content in the procedural system should reflect how current behaviour matches past experience rather than merely results from the past.

To understand that appeal to stored content plays a similar role we should focus on what individuals with ideomotor apraxia lack. Importantly, those suffering from ideomotor apraxia have a *representational* deficit, lacking the ability to recognize certain gestures (Wheaton and Hallet [2007]). As the ability to match a motor representation to one encountered in the past is lost, individuals with ideomotor apraxia may be compared in their recognitional abilities to amnesiacs that lost memories related to facts and concepts.

In individuals with ideomotor apraxia, it is the loss of a specific representational content — the inability to recognize a salute — that is referred to in order to explain behaviour. Similarly, it is amnesiacs’ inability to recognize semantic categories such as identifying a rabbit that is cited to explain their representational deficit. In both cases, stored content is cited to explain a recognition impairment, a deficit in matching past experience. The case of motor apraxia demonstrates, thus, that appeal to stored content in the procedural system plays an equivalent role.

A major objection against taking procedural memory to be a cognitive form of memory is that appealing to stored content to explain how the procedural memory system generates behaviour is redundant. The fact that descriptions of stored representations are explanatorily relevant across distinct memory phenomena indicates that this is not the case. Motor apraxia is a genuine case of ‘non-cognitive’ memory where appealing to stored content plays an explanatory role. The appeal to stored representations plays a significant role as it allows, for example, to distinguish between deficits that are purely motor and those that involve representational components. A process of encoding, storage, and retrieval may be said to equally apply to some cases of procedural memory. Thus, it is not true that stored content is redundant in explaining procedural memory.

**4 The Flexibility of Memory**

An idea central to Michaelian’s view, particularly regarding the appeal to distinct computational descriptions, concerns how stored information is made availableto an organism: ‘the subject has access to declarative memory representations. It is this that allows them to enter into the causation of behaviour in various indirect ways, via reasoning, imagination, etc.; if the subject were not to have such access, declarative memory would be unable to provide inputs to other cognitive processes’ ([2011], p. 179).

Michaelian can maintain that an alternative way to account for the lack of a common description involved in declarative and procedural systems has to do with the different forms of behavioural flexibility they provide. In contrast to the procedural memory system, Michaelian may contend, memories in declarative systems are flexiblyretrieved.

In this section, I focus on retrieval of information as an aspect in which memory systems may be said to be distinct. I discuss three ways in which Michaelian may allude to retrieval flexibility to disqualify procedural memory as a cognitive form of memory. In the following subsection, I argue that despite there being distinct ways to understand retrieval, flexibility is common to both declarative and procedural memory systems, thereby crossing the taxonomic boundaries that are meant to distinguish between these forms of memory.

Traditionally, memory systems were characterized in terms of declarative versus nondeclarative access to memories. That is, a memory system is declarative if it involves the individual's ability to verbally access a memory, and nondeclarative if an individual cannot provide a verbal report. However, as the distinction between declarative and nondeclarative memory is supposed to apply to non-linguistic animals, it is meant to capture a wider distinction than verbal accessibility.[[10]](#footnote-10)

On an extended conception, declarative and procedural memory characterize the way a memory system retrievesinformation. In declarative memory, information is retrieved in a way that is largely independent of the cues eliciting a memory allowing a context-sensitive response. Memory in the procedural system is more rigid in nature, where the expression of information is determined by the retrieval cues triggering a response. Hence, memory systems are not part of a unitary capacity because they do not all support the same kind of retrieval flexibility.

Retrieval flexibility, however, may be evaluated on a number of aspects (Machery [2011]; Buckner [2015]). One way in which behavioural flexibility varies involves automaticity. A distinctive mark of procedural memories is the automaticityinvolved in their behavioural expression. Automatic responses take many repetitions to develop, do not require many attentional resources, and are less sensitive to the impact of context (Schneider and Chein [2003]).

Declarative memories, in contrast, could be connected in indirect ways to other cognitive processes, such as imagination and inference. Recalling that I left the car lights on does not coerce me to get to my car and turn them off. Declarative memories are often given as output to inferences which conclusion one can ignore. Schacter and Tulving say it ‘represents an optional postretrieval phenomenon’ ([1994], p. 27). Hence, one aspect of behavioural flexibility concerns control, in particular, the extent to which the retrieval of memories and their effect upon behaviour is automatic.

The second way in which flexibility may vary is with respect to representational structure. Although also a form of control, structural flexibility is based on the ability to recombine and access complex memories (Schacter et al. [2018]). In declarative memory systems, it is possible to retrieve only part of a memory or to access it through distinct retrieval cues. The procedural system is characterized by the fact that information is unitized or might be retrieved according to definite sequences.

Maybe a metaphor would help. Imagine a building. If you could enter it from many different entries or visit only some floors without having to traverse the entire building, then this building is analogous to declarative memory. If you can access it only from specific entrances or are dependent on passing through certain floors to get to others, then this building is more like procedural memory.

Structural and control-based forms of flexibility often go together, but they might also depart. For example, one can automatically express part of a memory, recognizing a feature of an encoded category by recalling only the color of an animal. Structural flexibility, thus, places constraints that have to do with how memories may be accessed and experienced, not with our ability to control whether they are expressed.

Finally, flexible retrieval is taken to reflect an adaptive process, in the sense that stored information might be applied in novel contexts, different from the one in which that memory was encoded. This form of behavioural flexibility is characterized by the independence of the retrieval process from specific cues and the ability to generalize information to unfamiliar situations. It is, therefore, an important element that allows memory to guide behaviour, make inferences, and planning, through the use of stored information. Contextflexibility diverges from other forms of flexibility in being sensitive to changes in the environment rather than to an agent’s goals and needs (see, for example, Sterenly [2003]).

Memory systems may be responsible for flexible retrieval in any of these forms. Michaelian can, of course, adopt any form of flexibility and argue that memory systems differ on one of these aspects but not on others. In the next section, I present several examples showing that all three forms of flexibility apply to the procedural memory system and thus cannot serve to demarcate between procedural and declarative memory.

**4.1 The Flexibility of Procedural Memory**

Memory systems may be distinguished based on their capacity to support flexible behaviour through retrieval processes. Information from the declarative memory system is flexibly retrieved, while retrieval from the procedural memory system is not. In what follows I argue that not only that there are cases of declarative memory that lack features of flexible retrieval, the procedural memory system may exhibit features of flexible retrieval. Consequently, the identification of the declarative system as flexible and the procedural system as inflexible fails to properly characterize procedural memory.

First of all, it is important to realize that flexibility does not directly concern the semantic properties of a memory. Declarative memory systems such as semantic memory do not necessarily qualify as flexible neither due to how they process that type of information nor for the type of representations they process. There are instances of declarative memory retrieval that are both inflexible and involve the retrieval of semantic content. Individuals that undergo hypnosis can implicitly express autobiographical memories (Barnier et al. [2002]). One could interpret false memory effects such as the DRM effect as expressing automatic processing (Roediger and McDermott [1995]).

A paradigmatic case is semantic priming. Semantic priming refers to the improvement in speed or accuracy of response to a stimulus, such as a word or a picture, when it is preceded by a semantically related stimulus (nurse-doctor) relative to when it is preceded by a semantically unrelated stimulus (table-doctor). This type of facilitation is semantic in nature because it is produced by the semantic relation that holds between the connected stimuli, that is, nurse is semantically closer to doctor than table (McNamara [2005]). Semantic priming reflects a cognitive type of retrieval and is distinguished from repetition priming, where it is the perceptual features of the stimuli that are thought to drive the change in recognition ability (Tulving and Schacter [1990]; Gupta and Cohen [2002]).

The fact that there is an automatic capacity in which retrieval is not optional, but information retrieved is semantically linked to the cue eliciting the memory, shows that the semantic properties of stored information do not essentially concern flexible manipulation. This tells against the idea that retrieval from declarative memory is necessarily non-automatic. Furthermore, the memories retrieved in semantic priming are unitized, meaning that the entire memory is accessed and not its individual components. So, even in a structural sense, the fact that the declarative memory system involves semantic content does not amount to retrieval from that memory system being flexible. Retrieval in the declarative memory system is thus neither necessarily controlled nor are its components always individually accessed.

A possible response open to Michaelian is to say that semantic priming might belong in a distinct memory system, being ‘an exception that proves the rule’ ([2012], p. 187). And indeed, the idiosyncratic character of priming has led neuroscientists to classify it as a unique type of system. For example, Henke ([2010]) classifies priming in a system dedicated to rapid encoding of unitized items. Michaelian might rely on these suggestions to incorporate priming into a type of memory that shares many similarities with declarative memory while lacking some of its flexible features.

Adding borderline systems, however, puts pressure on the distinction between cognitive and non-cognitive memory systems that Michaelian seeks to establish. A memory system that is both declarative and inflexible blurs the distinction that is supposed to constitute the difference between cognitive and non-cognitive memory. Since phenomena that are both declarative and inflexible exist besides semantic priming, it is also unclear whether semantic priming could be treated as an outlier. Moreover, the case of semantic priming indicates that it is not semantic content or processing that makes declarative memory flexible. This gives reason to believe that it is not the properties associated with the declarative memory system that distinguish flexible and inflexible memory retrieval.

Regardless of whether declarative memory is always flexibly retrieved, the characterization of the procedural memory system as inflexible may itself be contested. Higher-level functions can be attributed to the procedural system with behavioural flexibility being considered critical for action. According to Christensen, Sutton, and Bicknell the flexibility of skillful motor behaviour demonstrates that ‘the [procedural] memory system is not well characterized as responsible for the acquisition of “habits and skills”’ ([2019], p. 713; See also De Brigard [2019] for similar claims). The nature of skill notwithstanding, it is inflexibility itself, I want to argue, that is a poor characterization of the procedural memory system.

Procedural memories may be said to involve all three forms of flexibility. Procedural memories may be retrieved in a voluntaryand controlled manner and explicit processes have been found to occur in procedural memory (Taylor et al. [2014]). For example, adjusting for external perturbations during movement has been found to heavily depend on voluntary corrections. Learned motor sequences can be recombinedthrough retrieval and might be accessed through different components in order to determine the best course of action. Through a process called motor chunking, many serial actions are grouped into units of commonly co-occurring actions, allowing the recombination of individual motor programs (Diedrichsen [2015]). Finally, the procedural memory system plays an important function in adaptingactions to precarious environments. Statistical-based learning used to update the brain’s models of the world on the basis of prediction error is thought to depend on the procedural memory system (Niv [2009]).

I want to focus on a paradigmatic case that I think exhibits all forms of flexibility just discussed. An important way in which procedural memory may be considered flexible involves motor imagery, the mental rehearsal of actions without engaging in the movements involved (Jeannerod [2006]). Despite its name, motor imagery critically depends on memory retrieval. Simulating a future movement in order to get it right depends on the retrieval of motor procedures one has previously learned.

Motor imagery exhibits all three forms of flexibility. Motor imagery plays a crucial role in action planning and, thus, is not automatically imposed. It is structurally flexible as one can simulate parts of previously learned sequences without considering the entire sequence. Finally, by using motor imagery, motor actions that were learned in the past may be applied to novel circumstances. The use of imagery allows the motor system to retrieve flexible motor procedures depending on contextual demands.

Take for example soccer players preparing to take a penalty shot.[[11]](#footnote-11) They imagine the direction in which they are going to kick the ball, recalling a pattern of movements from training they need to undertake to achieve their goal. They can decide whether to remember the movement from their own perspective or from a third-person perspective, recalling how they have done it in the past.[[12]](#footnote-12) The series of movements they imagine can be flexibly accessed, where only the parts from previous training they wish to focus on are retrieved. Crucially, by mentally rehearsing they do not retrieve information about a particular event but about the timings at which movements must be initiated and the exact spatial positions to place themselves to successfully kick the ball. It is the ability to flexibly retrieve a motor procedure that enables them to achieve the goal.

Michaelian may accept that motor imagery is important for flexible behaviour but still deny that it has anything to do with procedural memory. Consider, however, the functional similarity between imagining a motor sequence and executing a movement (Jeannerod [1995]). First, imagining a movement and executing it follow a similar temporal profile. It takes the same time to walk either physically or mentally to targets located at different distances (Decety et al. [1989]; Papaxanthis et al. [2002]). Both imagining and executing a movement, thus, depend on encoding information that corresponds to the unfolding of a movement over time.

Moreover, the physiological measures of imagining and executing movements are correlated (Collet et al. [2011]). Both imagined and actual movements result in increased heart and respiratory rate and a decrease in the skin’s electrical resistance. Since physiological measures express the activation of the autonomic nervous system that is not under voluntary control, the correlation of physiological measures reflects a shared functional role. Both offline and online retrieval of motor representations are constrained by the effort involved in movement execution (Jeannerod [2006]).

Finally, imagining and executing an action is subject to similar biomechanical constraints (Frak et al. [2001]; Dahm et al. [2016]). By asking participants to imagine how they would grip an object, it was found that the imagined expectations about the grip orientations fit the range of actual grips (Johnson [2000]). Participants were fairly limited in the range of possibilities that they could simulate in order to succeed in the task. It was the range of ways one could move a hand that enabled subjects to determine the right gripping orientation. The fact that biomechanical constraints influence motor imagery indicates that retrieving the information about the motor procedure takes into account the feasibility of performing it.

The similar time it takes for imagined and actual movements to unfold, the effort indicated by physiological cues during imagery and execution, and the fact that both imagined and actual movements are biomechanically constrained, means that the information guiding these actions comes from the same source. Specifically, the information driving motor imagery is retrieved from procedural memory.

Michaelian may concede the functional similarity yet reject that motor imagery belongs to the same memory system responsible for procedural memory. A second line of evidence concerning neuroimaging and neuropsychological studies mitigates this worry. These studies reveal that imagined patterns of movements rely on a similar set of mechanisms as the real action they simulate (Jeannerod [2006]).

According to the memory systems framework, the neural region underlying procedural memory is the striatum, which is part of the basal ganglia. Studies applying functional magnetic resonance imaging (fMRI) consistently find that the striatum is associated with motor imagery (Hétu et al. [2013]; Hardwick et al. [2018]).[[13]](#footnote-13) Neuropsychological studies have found that individuals with lesions in the basal ganglia and individuals with Parkinson’s disease (associated with degeneration of the basal ganglia), exhibit impaired motor imagery (Frak [2004]; McInnes et al. [2016]).

The fact that motor imagery belongs to the procedural memory system should not come as a surprise. The striatum controls for the selection and effort of motor procedures during movement execution (Shadmer and Ahmed [2020]). Motor imagery consists in mentally rehearsing movements to evaluate their relevance and the effort they demand. So, we should expect that the capacity for off-line retrieval of motor procedures would rely on the same neural mechanisms responsible for retrieving these motor procedures during action.

Does the re-enactment of previously experienced motor states have anything to do with the declarative memory system? declarative memory may obviously interact with retrieved motor imagery. Soccer players may recall instructions on how to kick a ball and adjust their movements accordingly. There may be cases where they remember kicking the ball in previous occasions rather than remembering how to kick the ball.[[14]](#footnote-14) But this shows that motor imagery and declarative memory interact, not that they are identical.

Inferring from these examples that motor imagery is a form of declarative memory ignores the purpose of motor imagery (Fridland [2021]). The ability of motor imagery to guide action depends on adequately retrieving the intended movementand not considering the right facts or recalling previous past events. Further, while thinking that declarative memory retrieval is sensitive to the same temporal and biomechanical constraints seems implausible, it makes perfect sense to associate these constraints with procedural memory.

Although procedural memory exhibits all forms of flexibility it is important to keep in mind that there are differences in how this flexibility is manifested, particularly when compared to the declarative system. One aspect of this issue concerns how long it takes for expertise to develop. Experts rely on retrieval strategies that organize the storage of information to facilitate access (Ericsson and Kintsch [1995]). Significant practice may be required for learning how to recombine components of a motor representation than it takes for similar processes in the declarative memory system. Thus, declarative memories can be acquired faster than procedural memories. The different encoding rate may influence the flexibility exhibited by procedural and declarative memory systems.

Note also that I do not mean to imply that all instances of procedural memory are flexible as motor imagery is. Some instances of procedural memory may only exhibit some forms of flexibility. Probabilistic classification, believed to depend on procedural memory (Knowlton et al. [1996]), is not voluntarily controlled but can still be considered adaptive. Other forms of procedural memory do not seem to be flexible at all, most notably, habit formation. Habits are acquired through instrumental conditioning where an appropriate response is required to receive an award (Devan et al. [2011]). Some habits, such as drug addiction, are not voluntarily controlled, cannot be recombined and express maladaptive behaviour. So, the flexibility of the procedural memory system can exhibit all, some, or none of the forms distinguished.

The different forms of behavioural flexibility underlying distinct memory systems have been taken as a central reason to dismiss procedural memory as a cognitive form of memory. The case of motor imagery suggests that retrieval flexibility may not support this position. Motor imagery, however, is just a representative example of a more basic point. Declarative memory does not amount to rigid memory retrieval nor does procedural memory equal flexible memory retrieval. Both declarative and procedural memory systems may exhibit flexible and inflexible forms of retrieving and manipulating stored information. Consequently, the flexible-inflexible contrast fails to distinguish between memory systems.

**5 The Possibility of a Unitary Capacity**

A distinction based on flexible and inflexible systems does not support a disunified view of memory. Is there any reason, however, to believe that memory is a unitary capacity? I think there is. In the following section I outline two ways to understand how memory systems can constitute a unitary capacity. Let me clarify at the outset that the ideas I propose are speculative. I offer these ideas to illustrate how a unitary mnemic capacity mightoperate. The extent to which memory is a unitary capacity would ultimately be determined by empirical investigation.

The first possibility involves thinking about memory traces as being functionally independent of memory systems. Consider the fact that organisms need to remember environmental features that are not exhausted by the particular functional specification of a single memory system. In many cases, memory traces would combine aspects of the world. A memory trace may consist of motor, autobiographical and emotional features. For instance, a memory of one’s wedding dance would combine the sequence of steps required to perform the dance, where and when the dance occurred, and the emotional vividness associated with the dance. Such memory traces are hybrid traces, composed of features computed by multiple memory systems. This approach takes memory to be a unitary capacity at the level of traces rather than at the level of systems.

Evidence for these types of cases can be found in lesion studies of animal learning (McDonald et al. [2006]). In a tactile discrimination task performed in an eight-arm radial maze, rats were provided with a food reward if they went to arms with textured ﬂooring and were not rewarded if they went to arms with smooth ﬂooring.[[15]](#footnote-15) Since the textured arm was session-specific, the animals had to combine contextual and instrumental-associative information to solve this task. Notably, rats with hippocampal or striatal lesions were impaired in performing this task, although each region is believed to support distinct mnemic functions. To understand these results, researchers appeal to hybrid traces preserving information from multiple sources.

On this approach, hybrid traces are distributed across multiple memory systems, thereby crossing taxonomic boundaries. Thus understood, memory traces are multidimensionalentities. The information carried by memory traces is generated by multiple memory systems working together. The multidimensional nature of these traces means that the information which can be extracted from them should be probed at the level of interactions between memory systems. A promising direction recently taken involves examining how a basic procedural memory signal, the reward prediction error, influences declarative memory tasks (Pine et al. [2018]). This approach moves beyond the dichotomy plaguing the classical view of memory.

The second way to think about a unitary mnemic capacity is to conceive memory systems not as stand-alone modules but as part of a meta-system. On this approach, distinct memory systems provide a form of division of labor to a general mnemic capacity (McDonald et al. [2017]; Ferbinteanu [2018]). This approach may be compatible with the first approach, insofar as traces are generated from the integrated interaction between memory systems.

McDonald and colleagues have suggested that, at least for mammals, memory systems assume different hierarchical relationships based on the degree to which each system inﬂuences behaviour at a global level. For instance, if a more detailed representation is needed, the hippocampus would be dominant. Thus, different memory systems assume control over the flow of information depending on the outputs required in a given situation.

According to Ferbinteanu, memory systems ‘respond to situational challenges by reconﬁguring […] and/or engaging in transient co-ordination among themselves to form temporary meta-networks’ ([2018], p. 62). Memory systems, on this approach, can transiently couple in response to task demands. In tasks that require specific behavioural output each memory system acts independently, while in tasks that require multiple behavioural outputs, memory systems integrate functionally, thereby constituting a transient memory meta-system.

Hybrid traces and meta-systems are ways in which memory might be a unitary capacity while being produced by multiple memory systems. Conceiving memory as a unitary capacity plays an explanatory role in these approaches. Namely, it is required to understand the organizational interaction between memory systems that produces such phenomena. In contrast to the classical hierarchical classification scheme, what is highlighted in these approaches is how multiple memory systems dynamically interact to produce mnemic phenomena that cross-cut the traditional taxonomy. This is an instance of how re-composing a mechanism changes our understanding of the phenomena (Bechtel and Abrahamsen [2009]).

To conclude this section, I want to very briefly consider two significant implications that could follow, if a unitary perspective is true. The first is that memory systems might not serve to distinguish different kinds of memory. This raises doubts as to whether well-accepted categories such as episodic memory are really as clear-cut as they appear. Rather than isolating episodic memory as a distinctive memory system, one could ask what role episodicity plays in a larger mnemic system. The second implication is that claims about memory not being a unitary capacity might be premature (Colaço [forthcoming]). Due to the complexity of its object of study, the sciences of memory have placed less emphasis on integration. Approaching memory systems from an interactive perspective opens the possibility of discovering general features of memory. I believe that there is ample reason to undertake the effort towards finding out.

**6 Conclusions**

Let us sum up. According to the memory system framework, memory is divided into distinct systems. Memory scientists and philosophers such as Michaelian rely on this framework as an evidential base to infer that procedural memory is not a cognitive form of memory and, as a result, memory is not a unitary capacity.

In this paper I have sought to establish the following claim - the procedural memory system is neither contentless nor inflexible. I have done so by undermining two criteria that are provided by Michaelian to distinguish procedural and declarative memory systems. The first criterion states that only explanations of declarative memory-driven behaviour appeal to stored content. The second criterion focuses on the difference in retrieval flexibility: The declarative memory system retrieves information flexibly while the procedural memory system retrieves information inflexibly.

Various examples demonstrate that no criterion that Michaelian offers holds. Stored content is called upon to describe paradigmatic cases of procedural memory such as motor apraxia. Thus, an appeal to stored content does sometimes play an explanatory role in describing the procedural memory system. The difference in retrieval flexibility also does not underwrite distinct mnemic capacities. Flexibility, on one hand, is not essential to semantic content, but may, on the other hand, characterize the procedural system. Finally, I suggested that not only do memory systems do not provide a principled way by which to infer that memory is disunified, but also the interaction between memory systems gives good reason to think that memory might be a unitary capacity.

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1. The identification of the episodic memory system with memory for the events of the personal past is contentious. A current debate about the function of episodic memory has to do with whether episodic memory concerns preservation of past experience or, alternatively, construction of representations of possible future episodes (Michaelian [2016]; Robins [2020]). Proponents of the constructive view consider episodic remembering to be one of several functions of a broader simulation system engaged also in future and counterfactual thinking. [↑](#footnote-ref-1)
2. The memory systems framework assumes that mnemic capacities correspond to specific neural structures. There is a growing dissatisfaction with this view among several philosophers and cognitive neuroscientists, leading some to argue for a rethinking of our cognitive taxonomies (Anderson [2014]). It might be the case that the medial temporal lobe is not exclusive for episodic memory or that memory systems are better described as encompassing a network of brain regions (De Brigard [2017]). The approach discussed here presupposes the validity of the memory system framework. If there are no memory systems at all then much of the evidential basis Michaelian relies on goes away. [↑](#footnote-ref-2)
3. Different taxonomies may carve memory systems using other categories such as processing modes (Henke [2010]). These categories emphasize other aspects of memory systems resulting in alternative taxonomies. Due to lack of space and as the philosophical discussion revolves around the standard taxonomy, I will not consider alternative taxonomies in this paper. [↑](#footnote-ref-3)
4. Note that the standard account might be a bit misleading. There may be cases where recollection is expressed through performance. Martin and Deutscher ([1966]) describe a person whose only way to recollect seeing someone dog-paddling is through actually doing the dog-paddle stroke. I discuss such cases considering the procedural-declarative distinction in section 4. [↑](#footnote-ref-4)
5. In what follows I use declarative/procedural and cognitive/non-cognitive interchangeably, but it should be noted that I mean these terms to refer to Michaelian’s distinction. [↑](#footnote-ref-5)
6. I am not the first to point out this case. Christensen et al. ([2019]) and Pavese ([2020]) have also used the case of motor apraxia to emphasize the explanatory role of content in procedural memory, particularly in relation to skill. [↑](#footnote-ref-6)
7. An additional type of apraxia that is sometimes distinguished from ideomotor apraxia is ideational apraxia, which is thought to specifically concern an impairment involving tool use. [↑](#footnote-ref-7)
8. An alternative explanation of this deficit is that patients with ideomotor apraxia can recognize gestures but lack the ability to retrieve these motor representations when asked to and thus cannot reproduce gestures. [↑](#footnote-ref-8)
9. Proponents of embodied cognition would not take this fact to be surprising as they consider motor systems to be a part of a cognitive system. Although the relationship between embodied cognition to Michaelian’s view is an interesting one, reference to the cognitive capacities of procedural memory appears to undermine Michaelian’s criterion of appeal to stored content. [↑](#footnote-ref-9)
10. The declarative/nondeclarative nomenclature is often substituted by an explicit/implicit memory nomenclature to accommodate this fact. [↑](#footnote-ref-10)
11. One does not need to be a professional athlete to understand this type of experience. If you have ever tried to dance in an unfamiliar style you might have had the experience of trying to remember the next move. [↑](#footnote-ref-11)
12. Researchers of motor imagery distinguish between several types of motor imagery (Guillot et al. [2009]). Visual and kinesthetic imagery are treated as separate processes, while visual imagery is itself divided into internal and external imagery. Internal visual imagery involves seeing the intended movement from one’s own perspective while external visual imagery involves seeing oneself performing the intended movement. The dual character of these memories bears a close resemblance to the field and observer perspectives in episodic memory (See also McCarroll [2018]). [↑](#footnote-ref-12)
13. Parietal and frontal regions also play a key role in motor imagery (Hardwick et al. [2018]). [↑](#footnote-ref-13)
14. There might also be cases where kicking the ball is the only way for them to express the memory that they kicked the ball on previous occasions. Recall Martin and Deutscher ([1966]) swimmer’s example. Even for these cases my point still stands. The function of remembering in these cases is not directly related to planning an action. [↑](#footnote-ref-14)
15. A radial maze consists of several spaced arms connected by a central platform. At the end of each arm, researchers can place food, thus creating an association between the arm and a reward such as food. The animals are required to distinguish between different tactile stimuli to receive the reward. [↑](#footnote-ref-15)