Memory and Technology: 4E Perspectives

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1. Introduction

In the last decades, embodied, embedded, extended, and enactive (4E) approaches in philosophy and the cognitive sciences have emerged as successful alternatives to the internalist view on memory. On a 4E view, memory is not a purely internalist cognitive capacity but is embodied, embedded, extended, and enactive. This means that memory systems, processes of remembering, and the contents of memories are shaped by and sometimes co-constituted by the body and environmental structures such as artifacts and technologies. Theorists working in this paradigm have different ontological and methodological commitments but agree that the unit of analysis must be enlarged from merely studying processes in the brain to studying how memory is embodied and stands in important relations to technological features of the environment in which we as embodied agents are situated.

The rationale for this special issue is as follows: whilst there have been special issues and handbooks about 4E cognition in general (Robbins & Aydede 2008; Menary 2010ab; Michaelian & Sutton 2013; Newen, de Bruin & Gallagher 2018; Villalobos & Videla 2023; Shapiro & Spaulding 2024), there has been no special issue dedicated specifically to 4E perspectives on memory and technology. Moreover, given the recent increase in using digital technologies to support memory, including generative AI such as large language models (LLMs) and virtual reality (VR), we believe the time is ripe for a special issue dedicated to analysing the relations between embodiment, memory, and (digital) technology. 4E approaches are naturalistic in nature, drawing from both conceptual analysis and empirical research. The targeted readership therefore consists of philosophers, but also empirical researchers interested in the relation between memory and technology, including psychologists, cognitive scientists, human-computer interaction researchers, memory studies scholars, design theorists, and others. In this introduction, we first present a brief history of thinking about memory and technology (section 2), we then outline the current state of the debate (section 3), and end with providing an overview of the contributions (section 4).

2. A brief history of thought about memory and technology

2.1 Technology as metaphor

We'll start this brief history of thought about memory and technology with an excursion into the history of psychology. Douwe Draaisma (2000) argues that we use technological metaphors to understand the properties of our biological memory. When people used wax tablets to write and store information, they used the properties of wax tablets to better understand biological memory, namely as a surface that can be inscribed and erased. Books and libraries allowed us to understand biological memory as a vast collection of information stored in a structured format. Phonographs allowed us to understand memory as something that can record and replay information. And digital computers allow one to understand memory as a system with files, folders, and search functions. So, we have the tendency, at least historically, to conceptualize our biological memory in terms of the properties of the available information technologies of the time.

Other scholars have similarly used technological metaphors to understand the properties of human memory. For example, psychologist Daniel Wegner (1995) argues that transactive memory systems, i.e., distributed memory systems composed of two or more humans, can be seen in terms of a computer network. A transactive memory system is a cognitive system comprising people in close relationships in dyads or larger groups who engage collaboratively in encoding, storing, and retrieving information. Examples include a long-married couple, a family, or a team of colleagues. Wegner identifies three properties of computer networks that he uses to understand transactive memory systems. These properties are “directory updating” (i.e., learning who in the group has specific knowledge or expertise), “information allocation” (i.e., assigning different pieces of information or memory items to various group members), and “retrieval coordination” (i.e., planning how to access information by leveraging the knowledge distributed among group members). Merlin Donald (1991) likewise used the notion of a network from computer science to better understand how biological memory systems and various external artifacts are connected and constitute an informational network much like a network of connected computer systems. We’ll briefly get back to Donald’s views below.

One of the first scholars to draw attention to the relation between memory and technology was engineer and designer Vannevar Bush (1945). He speculates about a mechanical device, which he refers to as a “memex” (a portmanteau of memory and expansion) that can store, organise, and make available information to its human user. Bush characterizes this device as follows:

> “A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory” (1945, p. 107).

Information in the memex such as photographs, periodicals, books, and newspapers is indexed and able to be called-up immediately to its user. In a further development of the notion of a memex, Bush (1967) added an interesting feature, namely that of “associative indexing” or personalised information trails. In Bush’s words:

> “The basic idea of which is a provision whereby any item may be caused at will to select another, immediately and automatically. This is the essential feature of the memex; the process of tying items together to form trails is the heart of the matter” (1967, p. 87).

These trails can be stored in the memex and when looking for a specific topic or concept, calling up a trail of items aids the user in finding information that is clustered together in terms of topic. Bush points out the human mind works through association and that for the memex to function optimally, it should also work through association. Bush here uses the properties of human biological memory to propose a design solution for a memory-aiding technology. In this sense, Bush reverses the comparison between biology and technology, as compared to Draaisma, Wegner, and Donald. The concept of associative indexing is considered a precursor to hypertext and the World Wide Web. Joseph Licklider (1960) and Douglas Engelbart (1963), both pioneers in computer science and design, were influenced by Bush's concept of the memex and went on to contribute to developing the personal computer and the Internet. Being an inventor, Bush's goal was not necessarily to conceptually better understand our relation to memory artifacts and technologies, but to improve it by building a personalized memex that can enhance our access to task-related information.

2.2 The species of the 4E framework

The species of the 4E framework (embodied, embedded, extended, and enactive cognition) started to emerge in the early 1990s, with important scientific precursors in artificial intelligence and robotics (Clancey 2008) and philosophical precursors in phenomenology and pragmatism (Gallagher 2008). Before the term "4E cognition" became popular, the term "situated cognition" was sometimes used (Robbins & Aydede 2008). Both 4E cognition and situated cognition are umbrella terms for any view that goes beyond the traditional internalist view on cognition, which conceives of cognition only as the internal manipulation of representations. On this traditional cognitivist view, cognition is a symbolic and disembodied process in which internal representations are manipulated according to logic-like rules. The term "4E cognition" started to be used in the early 2010s and one of the first times it is used in the literature is in a special issue of *Phenomenology and the Cognitive Sciences*, edited by Richard Menary (2010a). Whilst there are significant conceptual differences within the 4E cognition framework, which we'll outline below, the focus in this special issue is not on the differences but on how this broad framework can conceptualize the relationship between embodied agents interacting with memory artifacts and technologies.

An important landmark in the development of the embodied cognition approach was Francisco Varela, Evan Thompson, and Elenor Rosch's (1991) book *The Embodied Mind*. They argue for an "enactive" approach to cognition, conceptualizing the mind not as separate from the body but as actively involved in shaping and being shaped by the world through embodied action. Other important early works in embodied cognition theory are Rodney Brooks' (1999) *Cambrian Intelligence*, Georg Lakoff and Mark Johnson's (1999) *Philosophy in the Flesh*, and Paul Dourish's (2001) *Where the Action Is*. For a helpful overview and analysis of these books, see Michael Anderson (2003). In the context of this special issue, Dourish's book is of particular relevance. Drawing on phenomenology, Dourish argues that taking into account our embodiment and embodied interaction with computational artifacts, can help design more effective interfaces. Such interfaces and computational artifacts should exploit our specific embodiment and go beyond the traditional desktop model of computers. As embodied creatures, we are always situated in an environment, which is largely constituted by artifacts and cultural institutions. Our embodied interactions with artifacts have been, and still are, an important aspect of the embodied cognition approach.

The specific notion of a “cognitive artifact” was introduced by cognitive scientist and design theorist Donald Norman (1991). In his words, “cognitive artifacts are artificial devices that maintain, display, or operate upon information in order to serve a representational function and that affect human cognitive performance” (Norman 1991, p. 17). On this definition, cognitive artifacts are human-made material objects with a representational function used to influence cognition. These are artifacts used to perform a variety of cognitive tasks such as remembering, calculating, navigating, planning, and reasoning. Memory artifacts are thus a subset of this larger category of cognitive artifacts. Around the same time, Donald’s (1991) book *Origins of the Modern Mind,* came out. Donald argues that human memory is supported by cultural artifacts, or “exograms” in his terminology. "An exogram is simply an external memory record of an idea", whereas an engram is "a single entry in the biological memory system" (Donald 1991, p. 314). The development of exograms allowed our evolutionary ancestors to store information outside their brains and has created a new stage in our cognitive evolution, one that is characterised by the offloading of memory functions onto artifacts and external structures. Donald points out that exograms have different properties as compared to engrams. They are more stable, durable, easier to manipulate, and have more storage capacity. These informational properties can complement and often enhance the cognitive properties of the unaided brain. Exograms have significant consequences for our cognitive abilities. Donald points out that:

> “The brain may not have changed recently in its genetic makeup, but its link to an accumulating external memory network affords its cognitive powers that would not have been possible in isolation. This is more than a metaphor; each time the brain carries out an operation in concert with the external symbolic storage system, it becomes part of a network. Its memory structure is temporarily altered; and the locus of cognitive control changes” (Donald 1991, p. 312).

Cognitive anthropologist Edwin Hutchins (1995a) wrote an influential book *Cognition in the Wild*, in which he conceptualizes cognitive systems and processes as distributed across a team of humans and artifacts. His specific focus was on the way ship navigators interact with a variety of navigational tools and artifacts to successfully navigate a large navy vessel. This is not a task that a single human can perform in their head but can only be performed with a team of people interacting with several tools and artifacts. On this view, cognition is a collaborative, socially, and materially distributed activity (Hutchins 1991). Cultural practices of tool and artifact use shape and constitute cognitive systems and processes. The methodological and empirical focus should be on how information is transformed and propagated within such distributed systems, allowing cognitive tasks to be performed at the systems level.

The notion of distributed cognition was also influential in the educational and learning sciences (Salomon 1993). Educational theorist David Perkins (1993) argues that learning processes don’t only occur in the unaided embodied brain, but occur in distributed systems, i.e., brain-plus-artifact systems. For example, when a student uses a notebook to make notes, organising and storing information, "we could say that this person-plus system has learned something, and part of what the system has learned resides in the notebook rather than in the mind of the student" (Perkins 1993, p. 89). A distributed cognition approach has significant practical implications for education and assessment, rather than only training the unaided brain (e.g., by focusing on rote memorization), educators should also focus on teaching and assessing students how to exploit informational tools and the wider social and cultural environment (Pea 1993).

Further building on some of the above-mentioned work, philosopher Andy Clark (1998) developed a rich synthesis of research in neuroscience, robotics, artificial intelligence, and philosophy to argue that cognition is not solely an internal affair but is embodied and interwoven with features of the environment. In the same year, Clark together with David Chalmers published *The Extended Mind*, drawing attention to the constitutive connections between human cognitive processes such as remembering and artifacts. Clark and Chalmers (1998) argue that information in artifacts such as a notebook can play relevantly similar functional roles as information in biological memory. When an artifact is coupled to the embodied agent in the right sort of way, it can become part of the agent's cognitive system, in that way extending the agent's cognitive system. The extended cognition view and the other species of the 4E cognition framework are now prominent research programs in philosophy and the cognitive sciences, putting the relation humans have to (memory) artifacts center stage. One of the methodological implications is that to better understand memory and other cognitive capacities, we shouldn't only put subjects in brain scanners to study the neurocognitive mechanisms in their brain or ask them to fill in questionaries. Rather, we should enlarge the unit of analysis and also study how embodied agents interact with artifacts, other people, and cultural institutions as they perform their memory tasks in a variety of ecologically-valid settings.

3. Current state of debate

3.1 From analogue to digital

Early work on 4E cognition and memory artifacts primarily concerned analogue artifacts such as text and written symbols (Donald 1991), checklists for pilots (Norman 1991), navigational tools like compasses and maps (Hutchins 1995a), cockpit equipment (Hutchins 1995b), and notebooks (Clark & Chalmers 1998). More recent work on memory artifacts also concerns digital artifacts such as personal computers (Brey 2005), smartphones (Wilmer, Sherman & Chein 2017), and LLMs (Hoskins 2024). The recent transition from using mostly analogue artifacts to digital artifacts, including generative AI and LLMs, changes the nature of the landscape of memory artifacts. Memory artifacts are now more powerful, ubiquitous, and computationally autonomous. These properties are changing the relation we have to memory artifacts.

Some of the central questions in the current debate on memory and technology include the following: What role does embodiment play in our interactions with memory artifacts? How to characterize and demarcate the category of memory artifacts? How to carve up the category of memory artifacts? Are memory artifacts constitutive of our cognitive systems or mere causal contributors to memory systems? Are the long-term consequences of these artifacts on our biological memory capacities desirable? How do memory artifacts contribute to learning processes?

3.2 Embodiment and interaction

Lambros Malafouris and Maria Koukouti (2018) use an embodied cognition and enactivist approach to conceptualize how we interact with material culture. Their approach is characterized by the following claim: “memory traces, ‘internal’ or ‘external’, are mere and incomplete potential contributors to an open and context-sensitive process of remembering spreading across the body and the material world” (p. 163). This claim also applies to embodied memory or what cognitive scientists often refer to as procedural or implicit memory. So, for example, when we make pottery, we are in a situation in which the body reciprocally interacts with material culture. These procedural (inter)actions occur below the threshold of conscious awareness and the knowledge involved in the process is tacit. In such cases, the memory isn’t located in the brain, or even the body, but in the entanglement of embodied brains-interacting-with-material-culture. For the memory to come into being or to be enacted, we need to interact with the artifact. Their approach to embodied memory has precursors in classic phenomenology. Maurice Merleau-Ponty (1965) theorizes about a blind person using a cane to sense and navigate the environment. Martin Heidegger (1962) theorizes about a skilled carpenter using a hammer to act on the world. These tools are experienced as transparent equipment, are absorbed in the body schema, and mediate the relation their users have to the world (Ihde 1990). The approach of Malafouris and Koukouti can be summarized as follows:

> “The body remembers not so much through a process of passive recollection or the re-enaction of internal memory traces. Rather, the body remembers through the active identification or re-enaction of traces which are both internal and external. The external material environment and forms of material culture that surround us are not just cues or prompts for memory processes that happen inside our bodies or our heads. Instead, they are continuous and co-constitutive agents of recollection” (p. 175).

Other recent enactivist analyses of memory artifacts and technologies can be found in the work of Anco Peeters & Miguel Segundo-Ortin (2019) and Emanuele Prezioso & Nicolas Alessandroni (2023). For a more analytic view on embodiment and memory, we direct the reader to the work of Denis Perrin (2021).

3.3 Characterising memory artifacts

Memory artifacts can be characterized as material objects or structures that are used to functionally contribute to memory processes such as the encoding, storing, retrieving, and reconstructing of information (Heersmink 2027). Some of the core concepts building up this definition are memory, artifact, function, and use. Let’s briefly discuss these concepts in turn. Memory is a cognitive capacity allowing humans to encode, store, retrieve, and reconstruct information. This information can be about personal experiences (episodic memory) but also about general knowledge about language, concepts, and facts about the world (semantic memory). Sometimes these processes occur within the embodied organism and sometimes they occur partly outside the organism. Artifacts can aid these processes in virtue of their informational or computational properties. Most theorists working on memory artifacts conceive of memory and cognition as representational and computational (Donald 1991; Wilson 1994; Hutchins 1995; Clark 2008; Sutton 2010), whereas some conceive of it as non-representational (Hutto & Peeters 2018; Caravà 2021).

An artifact, as opposed to a natural object, is intentionally made or modified. Artifacts thus come into being through intentional action (Preston 2013). Hutchins (1999) points out that humans can also use natural objects for memory and cognitive purposes. Navigators can use the location of the sun or the stars as anchors for the cardinal directions and in that way "use" them for navigational purposes. The sun and stars are neither made nor modified by humans and thus are not artifacts in the strict sense of the concept. Heersmink (2013) therefore proposed the term "cognitive naturefacts" for such cases. It shows that humans go beyond merely using artifacts for their memory purposes but pragmatically use any environmental structure to aid their memory and cognition.

The function of a memory artifact is its causal effect on the user's memory states and processes and the role it plays in the user's overall cognitive economy. Its function is the reason why we use it. Theories on the notion of function in the philosophy of technology are useful in better understanding memory artifacts (Preston 2009; Heersmink 2016; Fasoli 2022). Sometimes its function is established when its use aligns with its designed or intended function, for example when a diary is used for remembering appointments. Other times its function is established through improvisation, for example when leaving a book on the corner of your desk as a reminder to bring it back to the university library (Heersmink 2016) or when bartenders structure drink glasses such that their sequence (e.g., wine glass, cocktail glass, beer glass) represents the order of drinks (Beach 1993). Finally, the notion of use is broad but can be characterised as obtaining information from the artifact such that some cognitive task can be performed. Using can be a quick saccade to your clock at the bottom of your computer screen, reading a text to understand some topic, clicking on a hyperlink to get to the next webpage, interacting with a VR environment, typing a query in a search bar, or rearranging letter tiles on a Scrabble tray as to aid word recognition. Using often involves some form of bodily interaction with the artifact, but not necessarily.

Sutton (2016) points out that we can taxonomize memory scaffolds in terms of their cognitive domain, the type of resource, and timescale. So, what memory capacity is scaffolded (e.g., semantic, episodic, or procedural memory), what is scaffolding it (e.g., cognitive naturefacts, artifacts, other persons, or cultural institutions), and at what rate the resulting learning and transformation occurs (e.g., the rate of occurrent cognitive processes, developmental processes, or evolutionary processes)? (see also Finley 2025). Heersmink (2024, 2027) identifies two timescales on which memory artifacts transform our memory capacities, namely on evolutionary and developmental timescales, and then outlines different artifacts and representational systems in chronological order, taxonomizing memory artifacts in terms of their historical and developmental order of occurrence.

3.4 Causation versus constitution

A lot of discussion has centered around the ontological question whether memory artifacts and cognitive artifacts truly extend our cognitive states and processes, in the sense that they co-constitute these states and processes (Rowlands 2009; Michaelian 2012; Rupert 2013; Palermos 2014). Proponents of the extended cognition approach argue that artifacts can become deeply integrated into cognitive states and processes, and in that way constitutively become part of those states and processes. Some theorists focus on functional parity between inner and outer resources as a criterion for constitution (Clark & Chalmers 1998; Wheeler 2011), whereas others focus on complementarity and integration (Menary 2007; Sutton 2010; Heersmink 2015). Opponents reject the constitutive claim and argue that memory artifacts and cognitive artifacts merely causally interact with and scaffold cognition (Adams & Aizawa 2001; Rupert 2004; Sterelny 2010). Neil Levy (2007) argues that it matters morally whether our minds extend and are partly constituted by structures in the environment (see also Farina & Lavazza 2022; compare Cassinadri 2022). Traditional neuroethical issues about how (neuro)technologies influence the brain are then extended to artifacts that co-constitute the mind. Other ethical issues discussed in relation to artifacts and the extended mind are mental privacy (Palermos 2022, 2025) and mental manipulation (Clowes, Smart & Heersmink 2024).

Related to the causation versus constitution question, is the extended knowledge debate. This debate is about the epistemic status of the information stored in (memory) artifacts (Lynch 2014; Heersmink & Carter 2020; Kallestrup 2024). According to the extended mind, cognitive states, processes, and systems are, under certain circumstances, co-constituted by external resources such as artifacts. If knowledge is a cognitive state, then by a similar line of arguing, there is no reason why knowledge can't also extend and be co-constituted by information outside the human brain. On this view, then, knowledge doesn't just reside in individual brains, but some information in memory artifacts becomes part of our knowledge base when used in specific ways.

3.5 Autobiographical memory, bad scaffolding, and cognitive offloading

Most extended and distributed cognition theorists focus on how artifacts contribute to practical cognitive tasks such as working memory (Clark & Chalmers 1998), navigating (Hutchins 1995a), calculating (Clark 1989), and remembering semantic content (Carter & Kallestrup 2016). The way artifacts contribute to autobiographical and episodic remembering hasn't received much attention, though that's now slowly changing. Sherry Turkle (2007) proposes the notion of an "evocative object", which are objects or artifacts that trigger (strong) personal memories or feelings. For example, a concert ticket used as a bookmark may trigger memories of that concert, driving an old car may trigger memories of past road trips, packing a suitcase may trigger memories of past holidays, etc. Digital technologies, too, can aid us in remembering our personal past. For example, lifelogging or self-tracking technologies are used to record a person's daily activities, experiences, and behaviors with the aid of wearable devices, sensors, and smartphone apps. This allows a person to create a lifelog, a digital database of one's past, which can be used to remember our personal past in much more detail (Bell & Gemmell 2009). The way artifacts are related to autobiographical and episodic memories is now a topic of growing interest both conceptually (Clowes 2013; Heersmink 2022; McCarroll & Kirby 2023; Fabry 2023) and empirically (Finley, Naaz & Goh 2018; Hutmacher, Appel & Schwan 2024).

Another recent trend is a focus on artifacts scaffolding the embodied brain in bad ways (Aagaard 2020; Timms & Spurrett 2023; Spurrett, Colombetti & Sutton 2025). Memory artifacts can badly scaffold the embodied brain in at least three ways. They can transform the embodied brain in undesirable ways (e.g., by weakening certain native cognitive skills), make the cognitive task more difficult to perform (e.g., by interacting with a complex, non-intuitive interface), or they can create moral or social issues (e.g., by causing privacy issues). Lucy Osler (2025ab) argues that the way we narrate and remember our personal past can be influenced by digital technologies such as self-tracking devices and social media. These technologies selectively present us with algorithmically-filtered information, creating a skewed and incomplete picture of our personal past. So, some interactions with our memory artifacts and our larger memory ecology can be counterproductive and even oppressive (Fabry 2025).

There is also a growing empirical literature on "cognitive offloading" in both children and adults. This literature, often inspired by and drawing from theoretical work in the 4E cognition literature, aims to better understand when and under which conditions children and adults rely on information in the environment (Berry, Allen, Mon-Williams & Waterman 2019; Armitage, Bulley & Redshaw 2020; Armitage & Gilbert 2025). Examples include counting on your fingers, setting an alarm, using a calendar, leaving a sticky note, or using a GPS device. However, Richard Menary and Alex Gillett (2022) argue that the term "cognitive offloading" is too passive and doesn't describe how memory and cognition are deeply enculturated and how artifacts are reciprocally integrated into our cognitive systems. From an extended mind perspective, the term offloading doesn't capture the complex, dynamic *interactions* between memory and technology. Nonetheless, this empirical literature elucidates the strategies we employ when we use information in artifacts to remember facts, knowledge, and experiences.

Part of this empirical literature is research on the Google effect, photo-taking impairment effect, note-taking effect, and what we will call the LLM effect. The Google effect describes the memory consequences of having access to internet applications such as Google Search and Wikipedia (Sparrow, Liu & Wegner 2011). This research shows that (1) when we do not know something, we are primed to use a computer to look it up, (2) when we know information is accessible externally, we put less effort into encoding it in the brain, (3) when we know information will not be accessible externally, we put more effort into encoding it in the brain and have better recall of that information, and (4) when we know information is stored externally, we often know where it is stored but not the exact content of that information. Having reliable access to information (on the internet) thus significantly transforms our memory systems, practices, and strategies.

The photo-taking impairment effect is about the phenomenon where we have fewer details in episodic memories of objects that one has photographed (Henkel 2013). When taking photos of (for example) museum objects, the process of taking photos interferes with attentional processes, which has downstream consequences for the level of detail in the memories of those objects. This effect doesn't occur because participants know the photos will be available later to aid them in recall, but because taking photos interferes with attention (Soares & Storm 2018). The note-taking effect describes the consequences of different writing tools on memory and understanding (Mueller & Oppenheimer 2014; Morehead, Dunlosky & Rawson 2019). For most people, writing with pen and paper is a slower process than writing with a keyboard and computer. This can be beneficial as it forces one to be more efficient when writing notes. Instead of taking notes verbatim, one must think through the information in one's head, which results in a stronger consolidation of that information in the brain. So, if one's goal is to memorize and understand content, then writing with pen and paper is the best way to perform the task. However, if one's goal is to have a more detailed written record of some lecture or meeting, then writing with a laptop is the best way to perform the task. Different offloading strategies thus have different trade-offs (Grinschgl, Papenmeier & Meyerhoff 2021).

Finally, a recent study shows that when students use LLMs to write an essay, it influences their semantic memory, in that they are unable to quote from the LLM-generated essay. Students who wrote their essay without the aid of an LLM were able to quote form their essay (Kosmyna, Hauptmann, Yuan, Situ, Liao, et al. 2025). So, when students use LLMs for their essay-writing tasks, it can negatively impact their learning and memory. Taken together, the above research shows that memory artifacts can transform our onboard biological memory systems in significant ways, in that way changing the equilibrium between biological and artifactual information-storage. How we should evaluate these transformations depends on our epistemic and cognitive goals, the availability and reliability of the artifact, the nature of the task, our personal, moral, and cultural values, and other factors (Heersmink 2027).

3.6 Future directions

The ultimate goals of a 4E theory of memory and technology are to have a complete empirical and conceptual understanding of the evolutionary and developmental trajectories of memory-artifact relations in different cultures and demographic groups. Conceptual research on how to best characterize memory artifacts and their relation to human memory capacities and empirical research in ecologically-valid settings should mutually inform each other. New results of experiments should be integrated into our best theories of memory-artifact systems. We should also be able to design memory artifacts such that they aid embodied agents in their specific needs, contribute to their cognitive flourishing, and to use such artifacts in a way that is consistent with our personal, moral, and cultural values. Achieving these goals requires an interdisciplinary approach in which philosophy and the cognitive sciences collaborate, exemplified by many of the papers in this special issue. In the next section, we'll give an overview of the contributions to this special issue.

4. Overview of the contributions

4.1 AI, digital technology, and memory

Pii Telakivi explores how remembering together with personalised AI systems is significantly different from remembering with other cognitive artifacts such as a photo album or a journal. Conversational AI systems like *HereAfter AI* or *Replika* can organise the personal information (e.g., photos, social media accounts, journal entries, and other information) that a user uploads into the system. The algorithm organises the uploaded information into a personal biography and users can chat with the algorithm to ask it questions about their personal past. Telakivi points out that we don't experience such systems as mere artifacts. Rather, we tend to anthropomorphise them and treat them as if they are quasi-others. They are not mere artifacts, but they are not fully human either. Their human-like and adaptive capabilities are relevant for how they aid their users in remembering their personal past. Telakivi also points out some potential risks such as outsourcing the emplotment of one's autobiographical narrative that might result in inaccurately remembering one's personal past.

Like Telakivi, Paul Smart, Rob Clowes, Joel Krueger & Michael Boniface explore how LLMs can function as personal memory systems. Using technologies to remember our personal past is something humans have done for a long time, for example with journals and lifelogging technologies, but recently emerging AI systems mark a new chapter in the history of technologically-augmented personal memory. Recent LLMS have multimodal capabilities, they can not only process language but also images, audio, video, and sensor streams. These capabilities allow such LLMs to aid their users in a variety of memory processes, including encoding, elaboration, retrieval, and joint reminiscing. The authors point out that depending on how the LLM is used, it can extend (i.e., co-constitute) the memory processes of its user. One issue we need to be aware of is that LLMs can hallucinate false informational output. In the context of using LLMs as personal memory systems, they can generate a hallucinated "memory", which may then cause false beliefs and memories in its user.

Mirko Farina, Xiaojun Ding, Andrea Lavazza & Changsheng Lai examine the potential of brain-computer interfaces and neuromorphic computing systems as empirical supports for the extended mind thesis. Many examples in the extended mind literature concern analogue artifacts such as notebooks or digital artifacts such as smartphones with which we have to manually interact. However, recent developments in neuroscience and artificial intelligence promise to create devices that can interface with the brain directly. The computational architecture of such devices can emulate the way the human brain encodes, stores, and retrieves episodic memories. Such a neuromorphic memory module can communicate signals directly to and from the hippocampus, in this sense functioning as an artificial hippocampus. Sensors worn on the body can record visual, auditory, and tactile information, which is fed into the neuromorphic module. This module encodes, stores, and retrieves this information in much the same way as the brain does and can communicate it, either directly to the hippocampus via a brain-computer interface or to a visual interface (perhaps embedded in wearable glasses) when the user intends or is triggered to remember an experience. If such a coupled system between human agents and neurotechnology would be possible (perhaps in the near future), it would constitute a new sort of extended cognitive system.

Cody Turner argues that avatars in virtual worlds such as computer games can extend the self of their user. Turner operationalises a narrative view on self and identity, according to which our self is constituted by our narrative, i.e., our remembered life story. The experiences users have when interacting with their avatar become episodic memories that build up an avatar-based sub-narrative, which is integrated into an overall life-narrative. In this sense, avatars are part of our narrative identity. This view has some important normative implications. If an avatar is a literal extension of a users' narrative self, then the avatar should inherit at least some of the moral status of the user. Avatars should thus be treated in a way that respects their autonomy and bodily integrity.

Linus Huang, Ying-Tung Lin & Michael Scott Sechman propose and develop a novel method for debiasing interventions. They propose a method to train people in an immersive VR environment with AI-generated avatars. The human-like appearance of the avatars and their ability to fluently engage in a natural conversation, can create realistic scenarios in which we can unlearn our existing biases. This VR environment scaffolds and extends the memory and affective processes of their users such that it enhances the efficacy of debiasing interventions. This effect is partly due to the highly personalised environment, its realism, and the anthropomorphising of the avatars, changing the attitude and biases some may have towards others. The authors propose a set of design principles to optimise the debiasing effect of AI-generated avatars and VR environments. They also point out some potential normative pitfalls of their approach related to algorithmic bias, privacy, autonomy, and opacity.

McArthur Mingon, Alex Gillitt & John Sutton review, analyse, and synthesise a wealth of empirical research on wayfinding and digital wayfinding technologies. They do so from the perspective of the 4E cognition framework. Research shows that using wayfinding technologies such as GPS-based navigation systems transform our cognitive maps, spatial cognition, and our ability to learn how to navigate an environment. From a purely internalist and individualist view, these transformations might seem worrying. However, broad brush normative statements about cognitive deskilling should be avoided. We must first realise that there are significant individual differences, which depend on patterns of use, interface design, and ecological context. Moreover, we should position our current use of digital wayfinding technologies in a broader historical and cultural context. Across the globe, different cultures have always used wayfinding tools that transformed our embodied brains and how we perform navigation tasks. Cognitive transformations caused by digital wayfinding technologies are not inherent to the technology but strongly depend on *how* these technologies are used in specific cultural contexts.

David Colaço develops a thought experiment in which a hypothetical technology allows an engram (or biological memory trace) to be externalised into a very specific sort of exogram. He suggests that rather than memories being stored in connectionist networks in the brain, it is possible that memories are stored in the brain as biomolecules such as DNA. If we were to extract such a DNA molecule from the brain of a biological agent and store it externally, then the agent in question can use the information contained in the DNA molecule to remember their past. The exogram would then have an identical substrate, properties, and dynamics as internal memories. Colaço identifies two waves of extended mind theorising, one based on parity considerations and the other on complementarity considerations. Parity deemphasises the distinction between the functional properties of engrams and exograms, whereas complementarity emphasizes the functional differences between engrams and exograms. He then draws out the implications of both parity and complimentary considerations for his hypothetical memory technology, pointing out that the distinction between agent and artifact is blurred. This blurriness, on Colaço's view, is difficult to account for in terms of present accounts of extended memory, which thus need to be updated.

4.2 Phenomenology, enactivism, and memory

Juan Diego Bogotá provides a phenomenological analysis of collective memory, i.e., shared memories of past events that are relevant for the identity of a group and its members. Drawing from Edmund Husserl, Bogotá identifies a distinction between egoic and non-egoic collective memory. Egoic collective memories are of relevant past cultural events that one experienced. Non-egoic collective memories are of relevant past cultural events that one didn't experience, usually because they happened before one was born. Four ways in which non-egoic collective memories are scaffolded are then identified. Such memories can be scaffolded through narratives, material culture, rituals, and embodied practices. One might, for example, learn about an important past cultural event through the narratives told by teachers or parents. Material culture such as monuments, statues, and paintings can also convey information about past cultural events. Rituals such as, for example, a military parade commemorating the end of Spanish rule in Colombia scaffolds collective memories. Finaly, certain behaviours sedimented into our body such as specific ways of gesturing may remind us of our membership to cultural groups and their specific past.

Mads Dengsø conceptualises how our memory and sense of time are hybrid capabilities, realised partly by our biology and partly by our sociotechnological environment. Temporal cognition is characterised as a vast range of cognitive, perceptual, and behavioral capacities associated with timing, memory, and the subjective experience of time. Importantly, we don't have a native, internal module for temporal cognition. Drawing from neuroanthropology and neuroscience, Dengsø argues that our temporal cognition is scaffolded and entangled with environmental structures. Endogenous neural and exogenous environmental factors work together to create our temporal cognitive abilities. Our current situation is characterised by a disruption and acceleration of our sense of temporality, which is caused by a disintegration with structures in our contemporary technological environment. Dengsø claims that rapid technological developments disrupt its alignment and integration with slower biological processes. This causes a paradoxical feeling of time as simultaneously displaced, speeding up, and slowing down.

5. Conclusion

The contributions in this special issue intend to be a statement of cutting-edge research on 4E perspectives on memory and technology. Instead of conceptualising memory as an individualist and internalist phenomenon, they show that memory systems, processes of remembering, and the contents of memories are shaped by and sometimes constituted by the body and environmental structures such as artifacts and technologies. Many of the contributions focus on recent digital technologies, including Generative AI, LLMs, VR, brain-computer interfaces, neuromorphic computing systems, and GPS-based navigation systems. Taken together, the analyses show that the landscape of our technological world is changing. Memory scaffolding and extending technologies are now more personalised, ubiquitous, and computationally autonomous, deeply transforming the way we think and remember.

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