Computational Model of Human Memory

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ABSTRACT

Theories of Extended Mind have evolved in waves to reach the present state of disagreement with regard to whether or not external artefacts become part of the mind when used for memory purposes. A four-step approach has been used to address and resolve this disagreement. First, a new component for models of mind which provides a saliency function is provided. This saliency function corresponds to computational elements found necessary in large mainframe computer systems for handling rich data environments. Second, there is introduced a Computational Model of Memory containing the new component which models the operation of human memory. The Computational Model of Memory contains four interoperative elements including the new component, short-term memory, long-term memory, and a cross-reference associator. Third, the work of Marcin Milkowski is drawn upon to obtain a general method of assessing a computational model's well-formedness, and the method is applied to prove the adequacy of the Computational Model of Memory. According to Milkowski's schema, the model satisfies most criteria for a well-formed computational model, including in particular a separation between conceptual elements of the model, and constitutive elements of the model, which while explicitly related, are required to subsist at separate logical conceptual levels. Fourth, the Computational Model of Memory is applied to outstanding arguments in Extended Mind to clarify and resolve several of these arguments. The model serves to highlight where the nature of the disagreement depends upon a category error of reference, and further resolves a key disagreement by demonstrating that the mind may treat external artefacts as an alternative realizable constitutive element of short-term and long-term memory.

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I dedicate this thesis to my father Joey Hempinstall, who in 2015 began having to rely on a notebook for storing new beliefs.

INTRODUCTION

The Problem

In the Philosophy of Mind, the individualism versus externalism debate centres on the role of one's environment in one's psychological processing and in particular meaning making. For individualists, the boundary of what constitutes psychological processes and processing is confined to the agent. For externalists, this boundary is drawn to encompass aspects of the agent's environment. The early view of externalism, exemplified by Hilary Putnam's "meanings just ain't in the head" (1975, 227), and Tyler Burge (1979), is that meanings are partly constituted by the agent's environment. (Burge's and Putnam's views will be more fully examined in Chapter 1.)

Andy Clark and David Chalmers describe this early standard view of externalism as one in which "the external features constituting differences in belief are distal and historical" and indistinguishable by external behaviour (1998, 18). By contrast, they argue for an *active externalism* in which the environment plays an active role in driving cognitive processes, a view also referred to as the *Extended Mind Hypothesis* (EMH) (1998, 2-5). Under the active externalism view, "the relevant external features play an active role in the here-and-now, and have a direct impact on behavior" (Clark and Chalmers, 1998, 13). To demonstrate, Clark and Chalmers use the example of Alzheimer's patient Otto who records details in his notebook using it to remember things such as directions to the Museum of Modern Art (MoMA) (1998, 12). They argue that the notebook is an extension of Otto's mind (1998, 10-18). In a key declaration, Clark and Chalmers list the criteria for Otto's notebook to qualify as part of his memory, namely: (i) the notebook is a constant in his life (1998, 13, 17); (ii) the notebook is directly available to him (1998, 15, 17); (iii) the contents of the notebook are automatically endorsed by Otto upon retrieval (1998, 11, 12, 18); and (iv) the information in the notebook has been previously consciously endorsed by Otto (1998, 12, 18). The last two criteria in particular entail Otto's past endorsement of the information in his notebook (Clark and Chalmers, 1998, 18).

In addition to Otto's notebook being at par with internal memory (1998, 11, 18), Clark and Chalmers theorize beyond the material world of paper notes to the virtual world of online data. They use examples of information stored in one's Filofax or certain information in certain files on one's computer system as potential qualifiers for status within one's cognitive system (Clark and Chalmers, 1998, 8, 17-18). Clark and Chalmers also broach the broader possibility of one's cognitive state being spread across the Internet. Regarding human-technology couplings, technological information systems appear to satisfy most if not all of Clark's and Chalmers' criteria for extension consideration (1998, 17-18). These devices satisfy past endorsement criteria of being constants in our lives, and we trust the content as our own. As well, the devices store information that could have otherwise been committed to internal memory, similar to the Otto example and the directions to the Museum of Modern Art. This situation of human-technological coupling introduces new challenges in understanding for instance, as to whether it is possible that portions of our minds are stored on external devices and if so, what is the risk, if any, of trusting the content of our memories to the online world.

With the ongoing evolution of increasingly sophisticated devices, the notion of a personal notebook evolves into a thin laptop computer, primarily designed for use in accessing cloud-stored information via the Internet. In the age of personalized technology, reliance on electronic personal information storage devices has increased to the point where many would feel lost without them, perhaps not able to recall frequently used phone numbers or even their own phone number. Beyond the straightforward problem of what happens if they are without their devices or electrical power for a significant period of days, (old fashioned backups or paper copies aside), there emerges the question of understanding what happens to the mind when it outsources work to the “cloud”, thus becoming increasingly reliant on properly functioning technological resources. While Otto’s notebook is ”to hand” and visible in its operation, the methods of information storage and lookup capabilities of Internet storage take memory extensions beyond fixed content into dependencies upon algorithms and equipment opaque to the user.

Continuing to speculate with respect to possible environmental candidates to serve as extensions, Clark and Chalmers raise the potential of socially extended cognition in which our mental states are constituted by other thinkers (1998, 18). Examples of such social extensions include long term couples, people in specific domains who may hold parts of each other’s beliefs, and a waiter at one’s favourite restaurant potentially acting as a belief repository of one’s favourite meals (Clark and Chalmers, 1998, 18-19). Other cases of possible social extension to one’s cognitive processes include “one’s secretary, one’s accountant, or one’s collaborator” (Clark and Chalmers, 1998, 18). Clark and Chalmers explain that central concerns in socially extended cognition are “a high degree of trust, reliance, and accessibility” (1998 18). As can be seen, these concerns parallel the past endorsement, parity and coupling elements of Otto and his notebook.

There is a general consensus in psychological research on memory structure that human memory consists of short term functionality (Short Term Memory - STM) (George Miller, 1956; Jackie Andrade and Jon May, 2004), working memory (WM) (K. Anders Ericsson and Walter Kintsch, 1995; Alan Baddeley, 2000) and long term stores (Long Term Memory - LTM) (Herbert A. Simon & Allen Newell, 1971). By way of contrast to Alzheimer’s patient Otto and his notebook as memory enhancement, an example of intense usage of internal memory is the case of journalist Joshua Foer which shows that a person can temporarily enhance at least their short term memory with training and practice. In 2005 Foer reported on the World Memory Championship at Oxford University, and impressed by what he had seen, spent the next year training his own memory by building on techniques he learned from his interviews with the competitors (Foer 2011, 131-174). Foer then applied these techniques to win the 2006 USA Memory Championship. While in peak form, Foer's memory was functionally enhanced, evidenced by being the fastest at remembering and recalling the sequence of a shuffled deck of cards, a task which would require an average person to use external memory storage such as a notebook to complete. From a substantive perspective, in comparison to a notebook user Foer was at a disadvantage as his enhanced memory is short term (he performs only one large memory task at a time) whereas a physical notebook contains many pages of entries, which can be consulted indefinitely.

Furthermore, during the task, Foer is occupied with remembering the sequence of the cards as part of the challenge, while a person using the notebook is in a position to think qualitatively about other things while the notebook holds the sequence of the cards. Foer had temporarily expanded his internal memory using unique relational cues to take advantage of memory chunking, a method of associating unique events with more mundane ones in order to facilitate short term recall (Foer, 2011, 139, 200). Foer's constructed memories are sufficient for the short term (memory competitions typically involve three tasks within a few hours) and provide a good example of how much the mind is capable of remembering on its own without the aid of external parts.

The Foer and Otto examples depict different ends of the spectrum of memory capability: one relies totally on the internal, while the other carries a significant aspect of his memory with him in a notebook. Substantively, Foer was able to internally store and recall massive amounts of information over the short term, but functionally, his associative power was primarily dedicated to the order of the deck of cards. By contrast, Otto's memory is substantively enhanced by using the notebook in that he is able to remember more than the Alzheimer's would normally allow him. Functionally his internal memory is impaired in that his associative power is handicapped by having to use notebook lookups and he is unable to retain any further new information. Foer displays an expert use of memory chunking and putting temporary memory constructs to work, while Otto lacks both abilities. These aspects will be discussed further throughout the thesis.

Insights can be drawn from the implications of adding external memory aids, in that the same device can be used for both trivial and non-trivial storage and retrieval. An electronic device can be used to store telephone numbers as well as to use brain game apps; a paper notebook can be used to store shopping lists and trivial information, as well as to do self-reflection. For instance, should you give me your phone number I can either write it down (or enter it into my device), or commit it to memory because I don't have a pen and notebook (or a technological device like a mobile phone) readily available. The next day I either recall the number from my memory or I recall it from my book. Though both methods achieve the same result of having the phone number at hand, the retrieval steps the mind performs in order to access the memory are different. Entailments of the consistent use of these retrieval methods will be explored in Chapters 5 and 6.

Daniel Kahneman's theory of cognitive processing which involves "System 1" (reflexive, automatic, quick, intuitive thinking) and "System 2" (deeper, logical, processing, complex, calculative thinking) (Kahneman 2011, 19-31) shows how practice is relevant to memory. For example, Kahneman uses a multiplication example to demonstrate “System 1” and “System 2” thinking in action. He explains how simple multiplication questions such as 3 x 9 are answered automatically by “System 1” thinking, while more difficult calculations, such as are required to get the product of 29 x 43 draw upon “System 2” thinking (2011, 21). From an internal memory structure view, it could be said that the example of 3 x 9 is a specific case of repetitive memorization of times tables, which are committed to Long Term Memory (LTM) versus knowing where to look to get the answer (a calculator or asking Apple’s electronic voice activated assistant ‘Siri’), which uses Short Term Memory (STM). Furthermore, an advantage of memorizing the 9 times table opens up the associative possibility of being able to see patterns and explore entailments of ‘learning’ the math. For instance, if one only resorts to using a calculator, awareness of how addition relates to multiplication, or more specifically how the digits of multiplicative products sum up to “9” in the answers of the 9 times table may never emerge.

Clark and Chalmers’ active externalism, demonstrated throughout their argument for Otto’s notebook as a memory substitute, and further as a mind extension (1998, 10-18), has paved the way for considering external artefacts, including other minds, as serving as extensions. Some cognitive theorists include a form of central processing. For instance, Jerry Fodor’s (1983) modularity theory of mind includes a ‘central meaner’ that loosely resembles a Central Processing Unit (CPU). Pure computational views of mind lean towards modeling what goes on in the head as akin to computational representations. In contrast to the previous concentration on cognitive processes, my project constitutes a focus on the extended memory part of mind extension.

The Aim

The aim of this dissertation is to address the question of whether or not there are implications to our increased reliance on external devices for mnemonic purposes, and if so, what the damages or benefits consist of. First I will argue for external human memory stores and theorize about the internal mechanisms involved in their storage and retrieval, resulting in a conceptual model. Second, the resulting model of internal and external memory will be used to assess the impact of increasing external memory usage on the mind by examining what specifically is lost or gained as a result of relying on external information stores. These findings are presented in Chapters 5 and 6, and will indicate that due to the nature of the information stored in memory extensions, our minds are affected in a substantive way, a functional way, or a mix of both.

Although the aim of this dissertation is to explore the substantive and functional effects of our increased reliance on external devices, and presenting possible implications. Despite the potentially strong consequences, it will remain for the reader to decide as to the normative significance of such reliance. As with the philosophical debates in the field of extended mind and memory, there are those who see only benefit to relying on the latest, fastest, more efficient technology. As well there are those who shun such advancements, refusing to participate (yet this becomes more difficult to resist with each passing day and each new invention). It is hoped that future research into this area of reliance on external technologies will expose at least some areas of benefit and prescribe ways to acknowledge and offset potentially negative outcomes.

Insofar as Clark and Chalmers defend their Extended Mind Hypothesis (EMH) based on Otto’s now renowned notebook, their theory has drawn attention from philosophers such as

Frederick Adams & Kenneth Aizawa (2008, 2010), Kenneth Aizawa (2010), Michael Wheeler (2010), Richard Menary (2006, 2010), Robert Rupert (2004, 2005, 2009, 2010, 2012, 2013) and Mark Rowlands (1999, 2011). Key philosophical ingredients of EMH that I will discuss include causal coupling (Clark and Chalmers, 1998, 4-5, 8, 12), parity (1998, 2, 10-18) and past endorsement (1998, 11-12, 18). Philosophers draw upon different facets of EMH arguments as they argue in support of, in partial support of, or flat out against them, with most of the attention on the cognitive aspects of the theory. For instance, Adams & Aizawa (2008) assert their "causal coupling fallacy" challenge to EMH. They maintain that being coupled or causally related to something is not the same as being part of that thing. On the other hand, Wheeler (2010) supports an extended functionalism, claiming that mental states in a cognitive system do not necessarily have to be bound by the body. Menary (2006) claims that Clark and Chalmers' parity principle (1988, 2), which introduces a functional aspect to EMH, is often misinterpreted by critics to include cognitive processes. Although critics of EMH arguments debate cognitive processes, mental states and location claims, they tend to at least agree on the notebook as a form of external storage. Here, areas of disagreement tend to be limited to the types of artefacts that could qualify as external memory, and how such external stores interact with internal memory.

In the following, external memory references will be argued for within the Philosophy of Memory, where a distinction between external and extended memory will be drawn. The argument concludes with a model of memory using a conceptual depiction of the mechanisms of the mind involved in the creation, sorting, storage and retrieval of internal and external memories. This model of memory draws support from developments in EMH, Philosophy of Memory, and from psychological and computational models of mind.

This dissertation will draw on extended mind arguments to show how extended memory is possible. This will be done by first examining what is at stake in Extended Mind Hypothesis (EMH) arguments in terms of mind and memory extension, then assessing and analyzing objections to the theory. The primary nature of the thesis argument is descriptive in that the model of human memory portrayed is the result of an assemblage of research and developments in Psychology, Cognitive Science and Computational Modeling. The philosophical elements of the thesis are grounded in debates about mind extension and what constitutes external mind and/or memory. I will show that there is no solid reason to reject the possibility of external memory stores.

The difference between external and extended memory is something that will be developed throughout the thesis. As a starting point, for the purposes of this discussion, external memory is considered to be synonymous with external storage. For example, a shopping list is a form of external memory since the items listed could have alternatively been “memorized” and stored in the head.

The notion of extended memory will become clearer when the thesis explores a distinction between memory and storage. For instance, photographic paper or electronic cameras are used to store and preserve images that can be reviewed in future. The images offer a snapshot of an unchanging moment (or several unchanging moments in the case of video clips) in time. It is a catalogue of one or more events that took place in the past, preserved so as they can be recalled as they were at that specific moment in time. These images rely on various types of external storage.

John Sutton argues that external memory (of the type stored in notebooks or devices) is subject to “objectification” in that it is preserved in such a way as to not suffer the fallibility of internal memory (2010a, 197-200, 206). With respect to external memory, the occurrence is captured in a solid format so that there is no doubt as to its content at a given moment in time, however external memory can lack contextual references. Internal memory, on the other hand, Sutton argues, is a “leaky container” at best (2010a, 197-200, 206). What I hope to gain from exploring a distinction between memory and storage is a way to satisfy the tension Sutton highlights between the human imperfection of internal memory and the “perfection” of external memory stored on devices (2010a, 197-200, 206).

Another area to draw upon for this distinction is the area of computer science. In the world of computers “memory” and “storage” are often distinguished by the context in which they are used. Computer files are stored in memory. A computer’s processing speed is affected by how much Random Access Memory (RAM) is available, yet in actuality RAM is a temporary working storage space, not a place that contains the stored content of the collection of our Word documents. This content is normally stored on magnetic media or within digital memory sticks which constitute a form of bulk storage. In Chapter 5 it will be shown how under certain circumstances, computer memory as storage for documents and other data elements such as photographs, could qualify as human external, or extended memory.

Thesis Statement

As a single statement, this thesis holds that there are artefacts that will serve as extensions of human memory, and increased dependency on such artefacts will affect the mind, both substantively and functionally.

The effects may play out positively: in a substantive sense resulting in the mind's capacity being affected in such a way that these extensions might strengthen the mind by allowing more time and energy to think about deep topics; and in a functional sense such extensions might allow the mind to remember more or to do so more efficiently as a result of enhanced storage and retrieval capabilities.

The effects may play out negatively in that the mind could become dedicated to trivial processing of directory information for external stores at the expense of not exercising its deeper thinking and associative capacities, knowing where to locate the information required, but sacrificing the depth of knowledge about that information.

The thesis argues for extended memory, and introduces original work in the form of a conceptual model of how the mind operates with respect to memory. Presented by way of a mechanistic view (Marcin Milkowski, 2013), there is provided the Computational Model of Memory (CMM), a mapping of the formal functional mechanisms in the architecture of memory creation and storage. It is a cross-domain schema that parallels and aligns mechanisms of the computer domain to that of the information processing aspects of mind. The CMM describes a formal relationship between the internal functional mechanisms used by computers to recall data, mechanisms that map onto processes done by the mind to create and use memories.

The proposal builds on the idea of external memory, arguing that there is no difference in kind between internal and external types of memory in the treatment of their contents; what differs is their location.

The Approach

This dissertation is organized into four major sections: the current status of Extended Mind Theory, its major objections and second wave arguments; computationalism and the benefits of computational modelling; the presentation of the model of memory as original research described under a mechanistic account, and the implications for the Extended Mind Hypothesis debate; and limitations and future work.

The first major section consists of three chapters, which survey the landscape of extended mind arguments, objections, and second wave arguments for extension. As memory is used by theorists as a base cognitive trait for extended mind arguments, there will be coverage of cognitive aspects at an appropriate level of detail with a focus on memory where relevant. Chapter 1 begins with an outline of Clark's and Chalmers' Extended Mind Hypothesis, wherein they propose that the boundaries of the mind go beyond the body, incorporating parts of the external environment. Clark and Chalmers' theory includes the nature of cognitive processes (1998, 6-8) and the concept of cognitive extension (1998, 9). Chapter 2 covers challenges to the Extended Mind Hypothesis on multiple fronts from Adams and Aizawa (2008, 2010) and Rupert (2004, 2005, 2009, 2010, 2013) and these arguments will be covered in turn. In Chapter 3, there is presented the second wave arguments for and against extension, wherein supportive theorists drop the "Hypothesis" and EMH becomes EM and objectors such as Adams and Aizawa and Robert Rupert maintain the hypothesis element, referring to EMH as the Hypothesis for Extended Cognition (HEC). Whereas Clark and Chalmers' (1998) original arguments for extension are based in past endorsement and parity claims, Chapter 3 reviews how the next wave of arguments are in the form of complementary couplings between the mind and external resources including other minds. This view is reflected in diverse ways including Mark

Rowlands' (1999, 2011) hybrid memory, Richard Menary's (2006) external scaffolding, Michael Wheeler's (2010) extended functionalism, and John Sutton's (2010) elaboration of exograms and transactive memory. The chapter further explains transactive, distributed and collective memory from that of a multidisciplinary perspective. The chapter closes with Robert Clowes' speculative approach to the kinds of E-Memory one can expect to encounter as a result of technological advances in technological devices and "cloud computing" (2013, 4, 17). Throughout Chapter 3 it will become evident that although it is not a stretch to see why electronic devices could be seen as external recorders of events, objects, and entries which need to be remembered, something else is required, another step, before these devices can be classified as part of, or an extension of, human memory. For ease of reference, two tables are included at the end of Chapter 3. The first table itemizes first and second wave Extended Mind arguments, and the second table lists the major objections. The tables set the stage for Extended Mind Theory as a candidate for computational modelling.

The second major section consists of Chapter 4, in which the advantages of computational modelling are considered. The nature and strength of modelling will be discussed along with early computational models including Herbert Simon and Allen Newell's (1971) simulation of human problem solving, David Rumelhart, Geoffrey Hinton and James L. McClelland (1986) neural learning model, Jerry Fodor's (1983) modularity theory, David Marr's (with Tomaso Poggio, 1982) levels of analysis approach to modelling in cognitive science, and Aaron Sloman's (1978) computational structure of an intelligent system. These models will be considered with respect to Milkowski's (2013) mechanistic view that provides a detailed set of standards for computational models. These standards, comprising well-formedness conditions for mechanistic models, includes three layers of explanation, including contextual, conceptual, and constitutive. It will become apparent that the mechanistic account offers advantages in constructing a computational model of a mind within its environment. Chapter 4 concludes with an example of a computational approach to memory in the form of Robert Wilson's (1994, 1999) argument for wide memory.

In the next major section there is put forth a stronger case for extended memory by appealing to a mechanistic account of a human memory model based in computational structures at the level of internal and external storage and drawing upon arguments related to Clark's and Chalmers' (1998) original hypothesis. It is claimed that what has been missing to date is an explanation of the procedure and mechanisms behind cross-referencing prior to information being externally stored, and the reverse process and mechanisms in retrieving information from external storage. At this point in the work there is drawn a distinction between extended storage and extended memory, and the difference between extended and external memory explained. This third major section of the thesis bridges extended mind and memory research to a specific model of human memory. Chapter 5 introduces original research, wherein the provided Computational Model of Memory highlights how the mind treats both internal stimuli/memories (those originating within the mind) and external stimuli/memories (those originating externally) as the same in kind. The model offers a depiction of how the mind processes information and how Extended Memory is possible.

The Computational Model of Memory consists of both internal and external parts and a description of the mechanisms used by the mind to store and retrieve information regardless of the storage medium. The model is presented under a mechanistic account which means that the conceptual processes depicted by the model operate within a contextual environment and are grounded in mechanisms which realize the function of the conceptual processes.

As part of the descriptive nature of a mechanistic account, this section then examines how the model aligns with developments in other disciplines showing compatibility with the Computational Model of Memory's internal buffer and cross reference structures. There is presented key work in the field of memory models, specifically Long Term Memory (LTM) additions by Alan Baddeley and Graham Hitch (1974), as well as Alan Baddeley's (2012) inclusion of the Episodic Buffer into the processing loop. The Computational Model of Memory may be used to trace the impact to the mind of consistently resorting to the "cloud" for instant answers and look-ups. Finally, relating the CMM back to the Extended Mind debate, the implications for the Extended Mind debate will be considered. The challenges to externalism and support for second wave accounts will be demonstrated using the Computational Model of Memory allowing for a recognition of flaws in some of the challenges.

In the final major section Chapter 6 provides a statement of limitations for the thesis and presents future work, describing research in the philosophy of mind and memory that could benefit from the model in action. With respect to limitations, the thesis scope addresses External Mind arguments and major objections, a mechanistic account of computational modelling and an exposition of the External Mind claims by way of a computational model of memory.

Research in the philosophy of mind and memory that could benefit from the model in action includes the implications of the mind bypassing internal deeper learning and cross-association by opting instead for direct external access to information. The research takes form in ethics, learning and development, and atrophying of the mind's abilities. The potential entailments of increased use of external storage, exploring the impact on the mind's ability to efficiently swap information in and out of memory, and the mind's ability to discern the quality and/or validity of external information can be modelled using the CMM. Finally, Chapter 6 also proposes how the model of memory could be implemented by way of a potential instantiation using a particular type of computer memory hardware, Ternary Content Addressable Memory (TCAM), which is currently in use for data network routers.

CHAPTER 1 THE EXTENDED MIND

The purpose of this section is to show that while the basis for Extended Mind Hypothesis rests upon the features of past endorsement and parity, it is not clear as to how the functional parity argument is sufficient to establish a cognitive system boundary that extends beyond the body.

This chapter and the next make up the first section of the thesis wherein the initial Extended Mind Hypothesis arguments and major objections are presented. In this chapter we will see how Extended Mind Hypothesis puts forth that the boundaries of the mind go beyond the boundaries of the body and incorporate parts of the external environment. We begin with an explanation of Extended Mind Hypothesis arguments.

1.1 Clark and Chalmers' Extended Mind Hypothesis

The purpose of this chapter is to explain Andy Clark and David Chalmers' Extended Mind Hypothesis, a theory that proposes that the boundaries of the mind or cognition span outside the body and include parts of the environment (1998, 2-5). As we will see in this and the next two chapters, while the argument for mind extension can be quite convincing, (it has many supporters and stands up to rigorous objections), it does not outright prove the occurrence of cognition outside the head. This chapter introduces the Extended Mind Hypothesis (EMH) from Clark and Chalmers' 1998 paper. In "The Extended Mind", Clark and Chalmers use the example of Otto, an Alzheimer's patient who relies on his notebook as a memory substitute, and his wife

Inga whose memory is intact, to argue for Otto's notebook being as equally reliable, functional and operational for him as Inga's internal memory is for her (1998, 10-18).

In this chapter we will see how EMH puts forth that the boundaries of the mind go beyond the body and incorporate parts of the external environment. The takeaway from this chapter is that according to Clark and Chalmers, an external part of the environment that satisfies functional parity as per the parity principle (1998, 4), and aligns with past endorsement as per defined criteria (1998, 18), sufficiently qualifies as an extension of mind (1998, 18). I will end the chapter by summarizing a list of requirements for extension that Clark and Chalmers (1998) claim Otto's notebook satisfies, setting the stage for Chapter 2 in which major challenges to EMH are presented and analysed.

We begin with an explanation of EMH arguments.

1.1.1 The Claim

Andy Clark summarizes the EMH claims as, first, that external cognitive or mental states are part of a causal web that enables agent behaviour (2010b, 1052), and second, that there is an *active* externalism in which the mind is part of a larger cognitive system (201b, 1047). To unpack what all of this means, we begin with a bit of background on externalism.

1.1.2 An Active Externalism

Clark and Chalmers (1998) explain that previously, externalist notions typically fell into the *passive,* standard sort most commonly associated with Hilary Putnam (1975) and Tyler Burge (1979), in which external features are far removed from the mind at the end of a causal chain, and do not affect one's behaviour (Clark and Chalmers, 1998, 2). Both Putnam's and Burge's externalism focus on content, and include the environment.

Putnam's view of externalism stems from two common assumptions about the meaning of mental states in relation to language, which are, first, that the meaning of terms in a language is determined by the mental states of the speaker using them, and second, that reference is a component of the meaning of a term. He argues that knowing the meaning of a term is more than just being in a certain *psychological state,* in the traditional sense (1975, 219). Under this view, psychology's use of *psychological state* is too restrictive and limits the scope of psychology to the individual. Putnam explains that this traditional notion of a psychological state means a two-predicate argument based on an individual at a given time (1975, 220). For example, to say that *I am six feet tall* implies a contextual time predicate of *at time t*. To say *I am in pain* implies the time predicate *at time t*. In science, however, such properties are restricted to the individual so that, for instance, within physics, to be six feet tall is a state or property.

Within psychology, to be in pain is a property of the individual. Traditional philosophers used this restrictive sense of psychological or mental state in the form of methodological solipsism in which no other individual is presupposed (Putnam, 1975, 220). Putnam argues that this particular use of the term *psychological state* has to be in a wide sense in order to address ideas such as jealousy, which involves a target to be jealous of (1975, 220). Using this wider sense of psychological state admits to an intension or internal state, and an extension as to what is referred to beyond the individual (1975, 221). Two people can each be jealous, but of different targets. From this basis, Putnam argues that two individuals can be in the same psychological state in the narrow sense even though the extensions of these states are different. In other words, "Extension is *not* determined by psychological state" (Putnam, 1975, 222, italics his).

To demonstrate his notion of externalism, Putnam uses an example depicting two planets, Earth and Twin Earth, which are identical except for the difference in the chemical composition of water on each planet (Putnam, 1975, 223). Putnam asks us to suppose that Earthians travelled to Twin Earth and were there for a number of years prior to learning about the different chemical make-up of Twin Earth water and Earth water (1975, 224). The Earth travellers were in the same psychological state before as after they learned of the difference (Putnam, 1975, 224). Putnam concludes, “Thus the extension of the term ‘water’ (and, in fact its ‘meaning’ in the intuitive preanalytical usage of that term) is *not* a function of the psychological state of the speaker by itself” (1975, 224, italics his). Since the chemical makeup of “water” is H_2O on earth and XYZ on twin earth, then part of the meaning of what is referred to as “water” is in the environment (Putnam, 1975, 225). In Putnam’s example, the meaning of “water” depends on the nature of the world in which it is found; meaning isn’t just in the head.

Tyler Burge’s externalism entails that the content of thoughts depend on more than just the individual, but in a different manner than Putnam. Burge argues that mental content is wide in that names and meanings are socially constituted parts of beliefs. He uses the example of an arthritis patient who (correctly) believes he has arthritis in his joints, but incorrectly believes he has developed arthritis in his thigh (1979, 78). The doctor corrects the patient’s terminology, indicating that arthritis occurs only in joints (Burge, 1979, 78). Burge next asks us to suppose a counterfactual case in which the word “arthritis” is used to define both joint pain and thigh pain, thereby validating the patient’s belief of having arthritis in his thigh (1979, 79). For the patient, the difference between the actual and counterfactual cases is “the patient’s mental contents differ while his entire physical and non-intentional mental histories, considered in isolation from their social context, remain the same” (Burge, 1979, 79). While the patient’s aches and pains remain the same, his belief about the nature of his disease depends on the social naming convention. Burge explains, “The *counterfactuality* in the supposition touches only the patient’s social environment" (1979, 79, italics his). What this amounts to is that if beliefs were mental states in the narrow sense, then the external social factors would not affect the content of those beliefs. However, as Burge demonstrates, external factors affect meaning only to an observer so meaning is not solely with the individual.

Andy Clark describes Putnam and Burge's standard externalist claims as being about "the role of the distal environment in the fixation of content" (2010b, 1047). This form of externalism is *passive* in that the external features do not affect the behaviour of the individual (Clark and Chalmers, 1998, 2). It is the historical environment that counts in the Putnam/Burge cases. By contrast, Clark and Chalmers argue for what they refer to as *active externalism* in which a cognitive system consists of a two-way interaction between a human organism and an environmental component creating a loosely coupled system wherein all of the components play a causal role, and "the relevant parts of the world are *in the loop,* not dangling at the end of the long causal chain" (1998, 1, italics theirs). For Clark and Chalmers, externalism is a thesis about the nature of cognitive processes, happening now, and playing an integral part no less relevant than brain features.

Clark and Chalmers' explanation of active externalism includes coupled components of both mind and environment as a cognitive system with equally important roles for all of the components, and without requirement for any or all of the parts to be in the head, including the mind.

> The human organism is linked with an external entity in a two-way interaction, creating a *coupled system* that can be seen as a cognitive system in its own right. All the components in the system play an active causal role, and they jointly govern behavior in the same sort of way that cognition usually does. If we remove the external component the system's behavioral competence will drop, just as it would if we removed part of its

> brain. Our thesis is that this sort of coupled process counts equally well as a cognitive process, whether or not it is wholly in the head (Clark and Chalmers, 1998, 2)

Due to the nature of the way in which the pieces of the cognitive system are linked, removing any of the parts will negatively impact behaviour.

Clark and Chalmers use the example of Alzheimer's patient Otto who records details in his notebook, implicitly trusting the contents and using it as a memory substitute (1998, 12). Otto consults his notebook much the same way in which his wife Inga (who does not suffer memory impairment) consults her internal memory, and the notebook governs Otto's behaviour in the same sort of way as Inga's internal memory governs hers (Clark and Chalmers, 1998, 14). Furthermore, if the notebook were to be removed, Otto's competence would drop, just as if any part of his brain were removed (Clark and Chalmers, 1998, 4). In other words, the notebook is as vital a part of the Otto-notebook coupling as is Otto's brain itself (Clark and Chalmers, 1998, 4). Since this coupled process of Otto and his notebook operates at par with cognitive processes in the head (4), Clark and Chalmers (1998) argue that the notebook is an extension of Otto's mind (1998, 10-18). Otto and the notebook are part of a larger causally coupled system, extended across brain, body and environment (Clark and Chalmers, 1998, 4).

Using the Otto example, Clark and Chalmers explain three conditions that must be satisfied in order for an artefact to be considered a mind extension: Otto and his notebook are *causally coupled* (1998, 4); the contents of the notebook have been *previously endorsed* by Otto (1998, 11, 12, 18); and the notebook conforms to the *parity principle* (1998, 4), operating for Otto the same way in which an able-minded person's memory operates for them. Each of these conditions will be examined in turn.

1.1.3 Causal Coupling

EMH maintains that the brain and environmental extensions form systems, and these are what comprise the mind (Clark and Chalmers, 1998). Clark is careful to point out that such a system "may include parts and processes that aid and abet cognition, without themselves participating in true cognitive processing" (Clark, 2010b, 1049).

Clark explains that cognitive systems consist of both neural elements and "fluently deployed" extra-neural elements such as notebooks (2010b, 1048). There is no doubt that as per EMH, cognitively interacting with one's environment consists of more than just neural processing and recognition. Clark and Chalmers argue that in certain cases, "the human organism is linked with an external entity in a two-way interaction, creating a *coupled system* that can be seen as a cognitive system in its own right" (1998, 4, italics theirs). In order to count as a cognitive process, the coupled process requires that all of the components must play an active role jointly governing the behaviour as would cognition, and that external components are considered equally as important as the brain such that if the external component were to be removed, the system's behavioural competence would drop accordingly (Clark and Chalmers, 1998, 4)

Clark and Chalmers raise a possible objection in that based on the criteria, one might suppose that *internal* causally coupled cognitive systems are not so easily separated, as in brain and body, whereas constant coupling of the individual and the environment can be easily separated (1998, 7). They note regarding reliability, non-body components of an extended system can no more be accused of being unreliable than the brain (1998, 7). They explain how the brain is subject to dangers of damage and malfunction and even loss of specific capacities due to intoxication and stress, and so this cannot be a sufficient reason for rejecting externally coupled systems (Clark and Chalmers, 1998, 7).

With cognitive extension accounted for, Clark and Chalmers next argue for beliefs being part of our environment, not just “brain bound” (1998, 11). Using the Otto and Inga example, Clark and Chalmers show how an external component can be part of a cognitive system (1998, 11). They argue that “beliefs can be constituted partly by features of the environment, when those features play the right sort of role in driving cognitive processes”, therefore showing that the mind extends into the world (1998, 12). To unpack how this is all supposed to work, we will now examine some key requirements for beliefs as part of overall mind extension.

1.1.4 Past Endorsement Criteria

Clark and Chalmers explain the reasons why Otto implicitly trusts the information contained in his notebook. These reasons are: the notebook is a constant in his life (1998, 13, 17); the notebook is directly available (1998, 15, 17); the contents of the notebook are automatically endorsed by Otto upon retrieval (1998, 11- 12, 18); and the information in the notebook has been consciously endorsed by Otto in the past (1998, 12, 18). The last two criteria entail Otto’s “past endorsement” of the information in his notebook. Otto trusts his notebook as a reliable source of his previously encountered information. He was sure of the information when made the notebook entry, and he trusts that the information is still trustworthy when he retrieves it from the notebook. Since Otto has previously endorsed the notebook entries and the notebook is always with him, his endorsement carries forward to subsequent consultations of the information. Clark and Chalmers use the past endorsement criteria along with the parity principle to establish that the externally recorded information can be used as belief substitutes for Otto (Clark and Chalmers, 1998, 18).

1.1.5 The Parity Principle

Clark and Chalmers outline the parity principle, which is used to explain how external elements qualify as mind extensions. “If, as we confront some task, a part of the world functions as a process which were it done in the head, we have no hesitation in recognizing as part of the cognitive process, then that part of the world is (so we claim) part of the process” (1998, 4). Active externalism entails a tight coupling between organism and environment, forming a cognitive system in which all components, whether internal or external, jointly contribute to the behaviour of the system (1998, 4). A failure of any of the components results in a drop in behavioural competence. It is not a case of whether the components are internally or externally located, but the resulting behaviour of the overall system that counts. External components such as pen and paper or calculators can be used in the same way as internal memory, and are considered at par with internal memory in the overall cognitive system (Clark and Chalmers, 1998, 4-8). Otto’s notebook is an element in his cognitive processing since the notebook is causally linked with him and his brain, the notebook satisfies the Past Endorsement Criteria, and it aligns with the Parity Principle (Clark and Chalmers, 4, 18).

1.1.6 Beliefs

In the case for mind extension, beliefs are explicitly focused upon and much of the argument for extended beliefs depends upon the rigour of the parity principle and how well it stands up to criticism. Since Otto’s notebook contains beliefs, it would follow then that these are also not “brain bound”, and also qualify as (external) mind extensions. Clark and Chalmers argue that the information in Otto’s notebook plays the same functional role for Otto that non-occurrent beliefs play for Inga (1998, 11-12). The notebook is part of Otto’s mind, and the location of the museum is one of his beliefs.

1.1.6.1 Occurrent and Non-occurrent Beliefs

According to the Otto and Inga example, when Inga remembers that the museum is on 53rd Street, she is recalling a non-occurrent belief (Clark and Chalmers, 1998, 12). That is, “the belief was somewhere in memory, waiting to be accessed” (1998, 11). Clark and Chalmers explain that Inga’s belief about the location of the museum was in her internal memory prior to her re-accessing that belief (1998, 11). Clark and Chalmers refer to Inga’s situation as a “normal case of belief embedded in memory”, activated in the context of her decision to go to the museum (1998, 12).

Consider then the same museum scenario involving Otto who relies on environmental information to support his failing memory processes (Clark and Chalmers, 1998, 12). Otto’s environmental support is his notebook, where he enters new information and consults old information for future reference. Clark and Chalmers claim that Otto’s notebook is a functional substitute for biological memory (1998, 12). They elaborate, “[Otto’s notebook] is central to his actions in all sorts of contexts, in that an ordinary memory is central in an ordinary life. The same information might come up again and again, perhaps being slightly modified on occasion, before retreating into the recesses of his artificial memory” (1998, 6). This means that like Inga, Otto recalls a non-occurrent belief about the museum’s location, even though his belief is retrieved from his notebook while Inga’s is in her memory (1998, 12). Clark and Chalmers explain, “just as Inga had her belief even before she consulted her memory, it seems reasonable to say that Otto believed the museum was on 53rd Street even before consulting his notebook” (1998, 12). In this sense, Otto’s notebook plays the same role as Inga’s memory does (Clark and Chalmers, 1998, 12). Furthermore, Otto’s belief no more disappears when he closes his notebook than does Inga’s when she is no longer conscious of her belief. In both cases, the information is available when needed; "the information in the notebook functions just like the information constituting an ordinary non-occurrent belief" (Clark and Chalmers, 1998, 12).

Clark and Chalmers explain how Otto is on par with Inga in the causal dynamics of the two cases (1998, 13). Inga's "occurrent" desire is straightforward; she believed the location of the museum prior to consulting her memory (Clark and Chalmers, 1998, 11). Inga's belief about the museum location was not previously occurrent, it was "sitting in memory waiting to be accessed" (Clark and Chalmers, 1998, 11). Otto's belief about the museum is also "occurrent" (Clark and Chalmers, 1998, 11). Clark and Chalmers argue that since Otto's notebook is a constant in his life in the same way as is Inga's brain bound belief, then the content of Otto's notebook *is* the belief (1998, 11).

In terms of functionality, Otto's notebook houses a non-occurrent belief (Clark and Chalmers, 1998, 11-12). Otto has the dispositional belief about the museum location before consulting his notebook. Such dispositional states could be achieved by "the biological system plus written entries in a constantly-carried and fluently deployed notebook or (for a more contemporary version) plus entries in the memory of a portable device such as an iPhone" (Clark, 2010b, 1048).

1.1.6.2 Residency of Beliefs

Clark and Chalmers argue that regarding the explanatory role of beliefs and desires, "Otto's and Inga's cases seem to be on a par: the essential causal dynamics of the two cases mirror each other precisely" (1998, 13). The overall process of storing and retrieving information in the head for Inga and via the notebook for Otto, is the same except that Otto's processing includes an external reference. To consistently explain Otto's case in terms of first consulting his notebook involves an extra step unnecessarily complicates the explanation. Clark and Chalmers argue, "We submit that to explain things this way is to take *one step too many*. It is pointlessly complex, in the same way that it would be pointlessly complex to explain Inga's actions in terms of beliefs about her memory" (1998, 13). That is, the first step is that of the belief being read or retrieved from memory, while step two is the process of being committed to occurrent memory. So Inga's "two-phase" processing is to recall her memory and then hold it in her mind as an occurrent belief. Otto's retrieval follows similar processing in that his first phase is to recall that there is a memory, and his second phase is to consult his notebook, which acts as his occurrent memory. Whether one step or two, in both cases the cognitive model outcome is similar, with Otto's notebook serving the same function as Inga's longer term memory (Clark and Chalmers, 1998, 13).

A possible counterclaim against Otto's belief about the museum being stored in his notebook is that the belief is merely activated by his desire to go to the museum (Clark and Chalmers, 1998, 14). The counterclaim entails that either Otto has no belief about the museum location until he consults the notebook, or that at best his belief is that the notebook contains the information about the museum location. Clark and Chalmers respond to this counterclaim as unnecessarily complicating the process. It has been shown that in terms of parity and past endorsement, Otto's notebook functions as a memory substitute. If the same sort of reasoning in the counterclaim was applied to Inga, her processing would also entail the complexity of explaining her actions "in terms of her beliefs about her memory" (1998, 13). In other words, adding another layer of processing, for instance, a belief about a belief, would merely add an equal step to both sides of an already balanced comparison without altering the result (Clark and Chalmers, 1998, 13). That is, both Otto's notebook and Inga's brain serve as constants in their respective cases. Clark and Chalmers conclude, “The essential dynamics of the two cases mirror each other precisely” (1998, 13).

The fact that Otto’s notebook is peripheral opens the door to questions about the status of his beliefs. That is, if Otto mistakenly used someone else’s notebook, would his beliefs change? I would answer this in the negative because Otto’s notebook contains pieces of Otto’s beliefs, the rest of which are in his brain. When Otto desires to go to the museum he already believes that there is a museum of some importance to him but he cannot recall the way there. He believes he has written down the location in his notebook and consults it for the directions. When Otto looks for the museum reference in his notebook, he knows the information is in there. If he searches a mistaken notebook, he will become aware that the reference he seeks is not there and that the contents of this notebook do not match up to what he expects to find. He will become confused since the mistaken notebook contents will not make sense to him, or as Clark and Chalmers claim, “if we remove the external component the system’s behavioural competence will drop, just as if we removed part of the brain” (Clark and Chalmers, 1998, 9). Pushing the wrong notebook scenario a bit further, beyond the point where Otto realizes the notebook is not his, suppose Otto curiously reads the contents of the mistaken notebook, and comes across an entry regarding an exposition at a different location, for instance, a community centre. In order for Otto to form a new belief about the community centre, he would have to consciously commit to that belief, and enter it in his notebook, since belief formation for Otto involves both an internal entry in his brain and an external entry his notebook. So, if Otto chooses to form the new belief, he would do as he has always done and write down the directions for the community centre in his notebook (once he finds his notebook). For Otto, reading someone else’s notebook would be like reading a book. The words would be someone else’s story, not previously endorsed by him. If he chose to identify with and believe some or all of the story, Otto would have to consciously commit to that belief and then write the contents in his own notebook. The parts of the story Otto chooses to dismiss altogether as entertainment or information are non-relevant as beliefs. For Otto, forming a belief involves consciously committing to the belief so that it can be cross referenced with the complimentary information about it that he enters in his notebook. Part of the belief is anchored in Otto's brain.

1.2 Summary

The Extended Mind Hypothesis (EMH) maintains that Otto's notebook as an extension of his mind (Clark and Chalmers, 1998, 18), that beliefs can be constituted in some part by environment (1998, 11), and that beliefs drive cognitive processes (1998, 12). There are four grounds for Otto's notebook as extended belief: the notebook is a constant in his life (1998, 13, 17); the information is directly available to him (1998, 15, 17); he automatically endorses the retrieved information (1998, 11, 12, 18); and the information has been consciously endorsed at some point previously (1998, 12, 18).

In this chapter I have demonstrated that a vital part of Clark and Chalmers' claim for mind extension is that the mind and its environment form a loosely coupled system with parts that are causally linked (1998, 4). Clark and Chalmers specifically state that pieces are not to be considered dangling at the end of a causal chain, but situated within the cognitive system with the mind (1998, 1). Frederick Adams and Kenneth Aizawa (2008, 2010) and Robert Rupert (2004) in particular, challenge the *causal* qualification claim within the loosely coupled system, primarily due to the fact that the mind is not privileged within the causal system thereby spreading cognition into the environment. These challenges will be elaborated upon in the next chapter.

CHAPTER 2 OBJECTIONS TO EXTERNALIST HYPOTHESIS

The purpose of this chapter is to show that major objections to Extended Mind Hypothesis arise in the form of boundary challenges to arguments based in functional parity.

This chapter provides commentary on and analysis of the strongest objections put forth by such major challengers to Extended Mind Hypothesis as Frederick Adams and Kenneth Aizawa (2008, 2010), and Robert Rupert (2004, 2009, 2010, 2013). As we saw in Chapter 1, Andy Clark and David Chalmers (1998) claim that the mind includes parts of the environment, supporting this claim with their functionally rooted *parity principl*e (1998, 2) and *past endorsement criteria* (1998, 18). Adams and Aizawa's (2008, 2010) challenges target causal explanatory and cognitive elements. Rupert's (2004, 2009, 2010, 2013) objections take the form of arguments against past endorsement, functional parity and causal explanatory power.

2.1 Adams and Aizawa

Adams and Aizawa claim that the group of arguments for mind extension pay insufficient attention to three plausible distinctions, which are: (a) that between causal *connection* and causal *constitution*; (b) that between X constituting part of a cognitive *system* and X constituting part of a cognitive *process*; and (c) that between cognitive and non-cognitive (2008, 10-11). Adams and Aizawa represent these distinctions as being principal weaknesses, the common denominator to all being the lack of an identifying "mark of the cognitive" (2008, 12).

2.1.1 Distinction One: Causal Connection and the Coupling-Constitution Fallacy

Adams and Aizawa contend that extended cognition theorists fail to attend to the difference between causal dependencies and constitutive dependencies (2008, 89). This problem arises when constitutive dependency conclusions are reached about the causal dependencies between cognitive processes and the brain-body-environmental processes (Adams and Aizawa, 2008, 88-89). Extended mind theorists do not provide plausible arguments to get from causation to extended cognition (2008, 90). An example of this fallacy is the simple coupling argument of a human using pen and paper. Adams and Aizawa explain that although brains and tools are jointly responsible for the result of using the pen and paper, it does not require that they constitute a single cognitive process (2010, 79-80). The interaction between the brain and the pen and paper can provide the basis for a causal process, in that the brain uses the pen and paper when performing a cognitive process. However this does not mean that the human, pen and paper together constitute a cognitive process, just that the pen and paper are used to facilitate cognitive processing. Adams and Aizawa argue that just because a process X is in some way causally connected to a cognitive process does not mean that process X is part of that cognitive process (2008, 91). Adams and Aizawa suggest there is a confusion about the difference between things that merely cause cognitive processes and things that are cognitive processes, the root of the problem being the uncertainty about what exactly cognitive processes are (2008, 101).

While Clark agrees that displaying causal connection does not entail cognitive extension, he asserts that the claim of the proponents of EM is that an object that is not usefully thought as either cognitive or non-cognitive can be become part of a cognitive routine (2008, 86). The effect of such a coupling is that the information is poised for “a certain kind of use within a specific kind of problem-solving routine” (Clark, 2008, 87). Not just any sort of coupling will do; all parts of the cognitive system are engaged and working, contributing to the cognitive processing. The coupling itself is a means to an end; it is the poising that does the real work (Clark, 2008, 87, 2010b, 1051). For example, in the case of a human using a pen and paper, the tools are coupled with the agent in just the right way so that the cognitive information can flow through the whole cognitive system. Clark uses what he calls the “standard neural story” as an example of how such coupling works internally. All elements of a neural pathway together engage as components of an integrated processing system in which both hemispheres are engaged, taking the right form to enable information flow (Clark, 2010b, 1051). It is not just the coupling that counts, but that the parts are incorporated into a single cognitive system (Clark, 2008, 84). In the case of Otto and his notebook, all parts are poised to form the cognitive system, and external parts adhere to the principles of parity and past endorsement. With the right sort of coupling, the information is poised for deployment by the cognitive system.

2.1.2 Distinction Two: Constituting part of a process or part of a system

Adams and Aizawa argue that just because some process X is part of a system, does not mean it does the work of the system (2008, 107). For instance, a duct is a critical part of an air conditioning system but the duct itself does not cool the air. This condition of not every process qualifying as taking on the role of the overall system also applies to processes and cognitive systems inside the head. For example, a human and pen and paper can constitute a system that together perform X, but it does not follow that every component does X. In cognitive terms, although the human performs cognitive processing, this does not mean that when engaged as a system that the pen and paper also perform cognitive processing. A human and pen and paper as a system do not establish an extended mind (Adams and Aizawa, 2010, 83). This line of thinking also applies to processing in the head. Arguing that cognitive processing is something the brain does particularly, Adams and Aizawa more strongly assert that not all intracranial processes are cognitive (2008, 107; 2010, 80). They explain that some of the brain's neuronal pathways serve to merely transmit or communicate information from one region of the brain to another without cognitive transformation (2008, 17). The transfer of information, whether internal or external, is not sufficient for cognitive processing status.

Clark argues that, at best, what Adams and Aizawa have explained is that it doesn't matter whether there is processing going on in the externally coupled elements, only that the element is an integral part of a certain cognitive architecture (Clark, 2010b, 1054). Criticizing Adams and Aizawa's restricted notion of cognitive processes as brain-bound, Clark highlights the difference between processes benchmarked on those of the brain and those considered as channels for information transfer (2010b, 1052). He notes that even if the corpus callosum, the part of the brain separating the two hemispheres, acts merely as an information transfer mechanism, it factors into human cognizing, playing an integral part in helping to realize cognitive architecture (Clark, 2010b, 1052). The neuronal parts that Adams and Aizawa describe as merely channelling information between brain regions are crucial to the specific complex patterns of information flow involved in human cognition. Furthermore, this pattern can be applied to human organism and external artefact couplings, such as Otto's notebook (Clark, 2010b, 1055). Regarding the status of cognitive processes, Clark replies to Adams and Aizawa that it is trivial as to whether the processing occurring in external elements is labeled 'mental' or 'cognitive', or whether inner neural working consist of both active processors and 'mere information buses' (2010b, 1055). While he concedes that a notebook is not itself doing any information processing, Clark does say that what does matter is the critical role such external structures play in enabling patterns of information flow (2010b, 1055). Clark describes a trusted notebook as “a node in a storage and retrieval circuit, a kind of buffer and link in a processing regime defined over brain, body, and world” (2010b, 1056). When up and running, these connective channels are deeply integrated into the processing loop (Clark, 2010b, 1057). In other words, the notebook serves as an information store within a cognitive processing circuit of brain and environment. Clark explains that there is an “interesting space of highly connectivity-sensitive cognitive architectures” between Adams and Aizawa’s notion of cognitive processes and cognitive systems (2010b, 1057).

2.1.3 Distinction Three: The Mark of the Cognitive

Adams and Aizawa claim that what is required from the extended cognition theorists is a way to distinguish the cognitive from the non-cognitive (2008, 77-86; 2010, 86-92). Suggesting their own version of what a mark of the cognitive might entail, they hypothesize that the cognitive would be different from the non-cognitive in that first, cognitive processing involves non-derived content, and second, cognitive processes are distinguished by processes particular to the brain (Adams and Aizawa, 2010, 86). They claim that such a mark of the cognitive matters because causal processes can be ‘transcranial’ and attention to causal processes alone misses the difference between what goes on in the brain and what goes on outside of it. In addition, if interest lies only in cognitive systems, then what could be missed is where cognitive processing leaves off and non-cognitive processing begins (Adams and Aizawa, 2010, 86). Being able to establish the difference between what is cognitive and what is non-cognitive is important for psychological research, especially when it comes to theories concerning the bounds of cognition (Adams and Aizawa, 2008, 86). Adams and Aizawa hold the view that while many projects in psychological research can proceed without knowing the exact nature of cognition, EMH is not one of them. They maintain the more radical the theory, the greater the need for a theory of the cognitive (2008, 86).

Adams and Aizawa pointedly take exception to theories which suggest that cognitive processing is a form of information processing (2008, 77). Accusing cognitive extension theorists, in particular Andy Clark and Mark Rowlands, of invoking “a promiscuous standard” for cognition in order to pinpoint what is cognitive, Adams and Aizawa point out that not all information processing is cognitive processing. Compact disc (CD) players, digital computers and cell phones process different types of information in different ways, but none of these are cognitive processors (Adams and Aizawa, 2008, 77; 2010, 89). A theory of the cognitive must acknowledge and account for the difference between information processing and cognitive processing as a narrow form of it (Adams and Aizawa, 2010, 89). Adams and Aizawa see a problem in that if information processing is acknowledged as being cognitive, then this opens the door to notebooks, computers and tools functioning as cognitive processing, and this goes against what cognitive psychologists contend (2008, 77, 86).

There are two ways to answer their objection, either by defining cognitive in terms of information processing, in which case devices as well as humans could qualify for cognitive status, or by defining the mark of the cognitive, that distinguishing element only humans (and perhaps some animals) contribute to “information processing”. While Adams and Aizawa dismiss much of information processing as not being cognitive (2008, 77), information processing can be an umbrella term for almost everything that a human being does. Human beings navigate the world dynamically inputting, interpreting, sorting and determining the disposition of the voluminous amounts of information they encounter. In other words, not all possible information processing is in the form of wristwatches, notebooks or individual tools.

Information processing is just that, the processing of information. The “processor” can be a human, a tool, a wristwatch, anything that is predisposed to process a particular type of information as input. Outside temperature as information is of no use to a calculator; likewise the numbers input to a calculator are of no use to a thermostat. A wristwatch is “oblivious” to traffic conditions, and a global positioning system (GPS) monitor does not process the price of sugar. If we want to say that the wristwatch is a cognitive system, then our definition would have to allow for any device or human accepting and processing information for which it is predisposed to process. As a component of a larger system, the function of the wristwatch is to display the time, which is something that a human would be predisposed to accept as input. Adams and Aizawa would categorize the wristwatch as an information processor, but not a cognitive agent, partly due to the lack of a definition, or a mark of the cognitive (2008, 77).

Andy Clark (2010b) and Mark Rowlands (2009) respond to Adams and Aizawa’s requirement for a mark of the cognitive in different ways. Clark dismisses the need for such a mark, while Rowlands attempts to define it by providing a criterion of the cognitive. We begin with Clark’s response.

Clark views Adams and Aizawa’s “proposed” mark of the cognitive as a question begging threat against EM proponents by benchmarking based on inner processes (2010b, 1050). Clark is saying that by insisting on inner cognitive processes as a standard for judging external processes, Adams and Aizawa have exposed something that Clark and Chalmers (1998) had hoped to avoid by way of invoking the Parity Principle. That is, Clark emphasizes that Clark and Chalmers were careful not to ask about specific details regarding the composition of cognitive processes. He stresses that the question raised by Clark and Chalmers was, “suppose this process were found in the head, governing behaviour as it does, would we then judge it as a cognitive process in good standing?” (Clark, 2010b, 1050). This question can be asked without first requiring a mark of the cognitive (Clark, 2010b, 1050).

Mark Rowlands’ responds to the mark of the cognitive objection by proposing a “criterion of the cognitive” (2009, 7-17). Stressing that objections to EM reduce in one way or another to the mark of the cognitive objection, Rowlands responds to this objection by constructing a “criterion of the cognitive” which outlines the *sufficient* conditions for a process to count as cognitive (2009, 7-17). He describes the *scope* and *character* of the criterion as a means to demarcate with reasonable precision the items that are of interest to his theory (Rowlands, 2009, 7). The *scope* of the criterion of the cognitive is that it attempts to demarcate “narrow” cognitive items from “wide” ones (Rowlands 2009, 7). Rowlands explains that (big ‘C’) Cognition is a fairly narrow form, opposed to perception and sensation and is restricted to post-perceptual processing (2009, 17). On the other hand (little ‘c’) cognition scopes out a broader sense of the term to include perceptual processing (Rowlands, 2009, 17). The *character* of the criterion is used to distinguish how cognitive processes work in the cognitive-scientific perspective, from “the philosophical project of *naturalizing* the mind” (Rowlands, 2009, 17, italics his). Rowlands believes it is a mistake to attempt the second project which would require a reductive definition of ‘cognitive’ in terms that are less than fully cognitive or completely non-cognitive (2009, 17). The *character* of Rowlands’ criterion is that of understanding what cognitive processes are by starting with what cognitive scientists regard as cognitive (2009, 17-18).

The first of the *sufficient* conditions that make up the criteria of the cognitive is that the process involves information processing. Rowlands expresses a strong connection between cognition and information processing, describing cognitive processes as a “series of transformations performed on information-bearing structures" (2009, 8). The second condition is that the proper function of the process is to make information available to the *subject* or to *subsequent processing operations* (Rowlands, 2009, 8). The third condition is that the information is made available by way of production of a *representational state* of non-derived content. Lastly, the fourth condition is that the process belongs to the *subject* of that *representational state* (Rowlands, 2009, 8). Rowlands explains how his principal example of the Peruvian *kvinu* officer who uses knots in a rope as a form of information storage, reflects his particular view of the cognitive (2009, 12). In the example, the officer, who is in a culture prior to the invention of external information storage, uses a system of knots in the form of a code in order to manipulate and exploit the rope to store information (Rowlands, 2009, 13). Rowlands claims that the knot is an external information-bearing structure, and the officer's deployment of knots, in the form of tying, modifying and reading them, satisfies the first condition of the criterion of the cognitive (2009, 13). The second condition is satisfied in that the manipulation or transformation of knots makes information available to the subject (Rowlands, 2009, 13). The non-derived representational states described in the third condition arise as a result of the information being made available "to the subject by way of its production in that subject of representational states that possess non-derived content" (Rowlands, 2009, 13). Rowlands bases this on the EM claim that cognitive processes always contain a "non-eliminable internal element", which is that of "representational states that possess non-derived content" (2009, 13). He describes the first three conditions as the *why* and *how* aspects of cognition. That is, the broadly understood function of cognition is "to make previously unavailable information available, either to subsequent processing operations or to the cognizing subject itself", and this is done by processes alone or in combination with processes of the same general sort, producing representational states. (Rowlands, 2009, 15). Elaborating on the fourth condition as the *who* aspect of cognition, Rowlands states that the specific details of the form and function of cognitive processes always belongs to someone or something, an entailment of which implies that there are processes that do not qualify as cognitive and are not "*owned* by anyone" (Rowlands, 2009, 6, italics his). This fourth condition is justified in that it "both explains why we have the intuition that intra-telescopic processes are not cognitive, and, more importantly, justifies this intuition" (Rowlands, 2009, 15). While the problem of determining ownership is more difficult than it seems, Rowlands notes that it is facilitated by adherence to the other conditions in the criterion of the cognitive (2009, 15). The problem of ownership of cognitive processes is also described as "cognitive bloat", which will be explored in the next section addressing Rupert's objections.

2.2 Rupert

Robert Rupert claims multiple areas of dispute with extended cognition theorists. He distinguishes between what he calls the Hypothesis for Embedded Cognition (HEMC) and the Hypothesis for Extended Cognition (HEC), claiming that the theories offer competing explanations of various types of cognitive phenomena (2004, 395). HEMC is an interactive cognitive approach that is bound by the organism, while HEC is a theory in which cognitive states or processes go beyond the body and into the environment (Rupert, 2004, 395). Significantly less radical than HEC, HEMC's focus is on obtaining an understanding of the cognitive processes that an organism uses in her cognitive work while exploiting her environment (Rupert, 2004, 395). HEC implies setting aside this focus on a "traditional subject" by expanding the unit of analysis to include both the organism and her environment (Rupert, 2004, 395). Rupert argues that unless it can be shown that HEC offers superior explanation of cognitive phenomena, all else being equal, cognitive science should endorse HEMC over HEC, due to HEMC's more conservative methodology (2004, 395). Since HEMC is the simpler theory, a substantial argument would be required on behalf of HEC in order for it to be shown as the preferred theory over HEMC (Rupert, 2004, 401). Rupert identifies and evaluates what he sees are the two types of supporting HEC arguments, concluding that these arguments are only sufficient to support an "embedded" cognition, not "extended" cognition, and so there is no good reason to accept HEC as the preferred theory (2004, 401-407). The *intuitive* argument involves the past endorsement requirement and the criteria derived from it, while the *natural kinds* argument entails issues regarding generic kinds and causal explanatory power. Each of these types of arguments will be examined in turn.

2.2.1 Intuitive Argument: Past Endorsement Dilemma

Clark and Chalmers' past endorsement criteria for Otto's notebook which is said to contain his beliefs are: (a) the notebook is a constant in his life; (b) the notebook is directly available and always with him; (c) the contents of the notebook are automatically endorsed by Otto; and (d) the contents were previously consciously endorsed by Otto (1998, 17). Rupert claims that the HEC theorist faces a dilemma with regard to either acceptance or rejection of the fourth criterion of prior conscious endorsement, in that on the one hand acceptance of such past endorsement would collapse HEC into HEMC, while on the other hand rejecting past endorsement leaves three weak criteria that can be too easily satisfied (2004, 402). We will now discuss each horn of the dilemma in turn.

Detailing the first horn of the dilemma, Rupert argues that acceptance of the conscious endorsement requirement for beliefs undermines the HEC theorists' argument in two ways

(2004, 405). First, it privileges the internal by requiring external beliefs to be endorsed internally, which Rupert suggests would imply the organism's use of external resources as tools to supplement the organism's thinking (2004, 405). That is, since belief formation requires conscious endorsement, which is an internal process within the boundary of the organism, the organism is privileged and the external resources are supplemental tools and reliant upon internal consciousness (Rupert, 2004, 404). Therefore, conscious endorsement actually privileges HEMC over HEC since its requirement shows an interactive cognitive system that is bound by the organism.

Regarding the second horn of the dilemma, Rupert argues that conscious endorsement runs into trouble establishing a boundary as to which previously endorsed beliefs are considered as belonging to the organism (2004, 403). Rupert claims that using telephone directory assistance is a counterexample to past endorsement since all of the phone numbers are trusted and believed by an organism, yet each number has not necessarily been previously endorsed by the organism (2004, 403). He notes and counters Clark and Chalmers' (1998) view that a person can have and acquire non-conscious extended beliefs (2004, 404-405). Arguing that while the acquisition of non-conscious extended beliefs would satisfy the problem of explaining our trust in phone directories, Rupert suggests the requirement of mandatory past endorsement for extended beliefs but not for non-extended beliefs seems arbitrary and so it is best to give up the criterion (2004, 404). He concludes that HEMC best accommodates the scenario of internal conscious privilege and an organism using external resources interacting with her environment (Rupert, 2004, 405). Pressing on, Rupert argues that once past endorsement is no longer a requirement, the three remaining criteria easily succumb to obvious counterexamples such as trusting telephone directory assistance (2004, 402-405). That is, the directory is a consistent, directly available and trusted source of information without an organism having previously consciously endorsed its contents (Rupert, 2004, 402-404). Summarizing the intuitive argument dilemma of past endorsement yields acceptance of past conscious endorsement as favouring an embodied view, while rejecting past conscious endorsement results in boundary issues as to what constitutes extended beliefs. Rupert indicates that either acceptance or rejection of internal conscious privilege shows that there is no reason to prefer HEC over HEMC (Rupert, 2004, 401-405).

2.2.2 Natural Kinds Argument: Granularity Dilemma

What has become known as the *natural kinds argument* begins with Clark and Chalmers' claim that "What makes some information count as a belief is the role it plays, and there is no reason why the relevant role can be played only from inside the body" (1998, 14). Clark and Chalmers assert that, "By using the 'belief' notion in a wider way, it picks out something more akin to a natural kind" and as a result, "the notion becomes deeper and more unified, and is more useful in explanation (1998, 14). Rupert outlines a dilemma facing the HEC theorists' natural kinds argument as having to accept causal explanatory kinds as either fine-grained or coarse-grained, each of which stipulation fails for different reasons (2004, 2013). Given that cognitive psychologists are interested in fine-grained properties, Rupert projects that the first alternative is not likely to yield extended natural kinds at all, while the second alternative will yield extended kinds unlikely to do substantive causal-explanatory work (2009, 6). We will now unpack each horn of the dilemma proposed by Rupert.

Rupert defines a natural kind as, "simply the causal-explanatory properties and kinds of the successful sciences, or to be a bit more careful, the properties and kinds that our sciences attempt to identify" (2013, 28). Additionally, in order to be useful in revealing which properties play a genuine causal-explanatory role in cognitive science, natural kinds would have to appear in sufficiently large quantities and in a range of successful models (Rupert, 2004, 407; 2013, 40). Describing what he means by causal-explanatory, Rupert states, “Broadly speaking, causal-explanatory kinds are those that support successful induction and explanatory practice in everyday life and, more to the point, the sciences” (2004, 406).

Rupert argues that in the case where causal explanatory kinds are individuated as fine-grained, these properties would have to be shown to produce for instance, memory-related behaviour, and there would have to be sufficient evidence and a vast number of occurrences of such properties in order to alter the way in which cognitive science is done (2004, 407, 418-419; 2013, 33-40). Rupert highlights the concern that benchmarking (that is, using something as a basis in a comparison) to fine-grained human states restricts the kinds to internal, which works against the external states the natural kinds argument sought to include (2013, 33, 40). Rupert concludes that the fine-grained argument fails because the kinds that can be expected to be found in the human environment are not of the same internal fine granularity that would be of interest to cognitive scientists (2013, 40). The possibility of extension is ruled out based on using the inner as a benchmark and then ruling out the possibility of external fine-grained kinds.

In the case of the HEC argument having to accept causal explanatory kinds as coarse-grained, Rupert claims this reduces explanations to HEMC equivalent (2004, 418-419, 424; 2013, 33). Since he has ruled out fine-grained kinds, Rupert supposes that HEC theorists must be appealing to “a taxonomy that includes overarching cognitive kinds-kinds that cut across the organism’s boundary” (2004, 406-407). Rupert outlines that his argument strategy is to begin by focusing on memory as a specific kind of cognitive state, and to show how a sufficiently coarse-grained generic form of memory that includes both internal and external components does not improve HEC’s prospects (2004, 407). His plan is to show that generic memory provides little to promote the adoption of HEC over HEMC, then conclude there is no reason to expand the argument by analogy to other cognitive states (Rupert, 2004, 407).

Rupert sees generic memory as analogous to generic "knowing" in the sense of knowing where to find information, and this to him does not require a cognitive explanation (2004, 421). He puts forth an example of a man who lives in a library and who knows and perhaps even remembers everything in all of the books he has accessed as a case of generic knowing (Rupert, 2004, 421). In the example, a cognitive explanation is not required since the general notion of access to information and the way in which the organism tries to locate the information are what getting the right answers depend on (Rupert, 2004, 421). This example shows there is not enough explanatory power to warrant seeing the content of the books as part of the library dweller's memory and so by the principle of conservatism, the explanatory power of HEMC suffices (Rupert, 2004, 421). Rupert's formulation of the natural kinds argument depicts an "all or none" granularity issue for cognitive extension. That is, the fine-grained view restricts cognition to the internal, while a coarse-grained view leads to vague and potentially overly inclusive cognitive boundaries.

2.2.3 Functionalism: Empirical issues

Having shown that the past endorsement and natural kinds arguments do not work, Rupert tries to take down HEC over functional equivalency. Rupert argues that the functional requirements for HEC are motivated by empirical considerations, something he labels "empiricalist functionalism", a requirement that if seriously adopted leads to "cognitive bloat" and boundary issues (2004, 422). First, we will explore the functional aspect of Rupert's argument followed by an analysis of what Rupert means by "cognitive bloat", then provide some examples of boundary issues.

Explaining what he means by empiricalist functionalism, Rupert outlines his formulation of the functionalist argument for HEC in which a mental state can be extended beyond the organism, as requiring (a) that a mental state of a certain kind is realized by whatever physical states plays the functional role that is characteristic of that kind, (b) that some of these realized kinds have physical components external to the organism and (c) that a mental state includes all components of its realization (2004, 422). This view is motivated by *empirical* considerations, as the requirement of HEC's functionalism is "empirically productive service" (Rupert, 2004, 423). According to Rupert, the type of functionalism required by cognitive science is one that involves a form of "psycho-functionalism" which would be able to account for the roles of mental states in accordance with psychological theories (2004, 423). Rupert's requirement boils down to a HEC functional account of mental states and he uses memory as an example of the difficulty in acquiring functional equivalency for external mental states. Memory formation, learning, forgetting, and the generation effect must be accommodated by externally functionally equivalent mental states, something he denies is possible (Rupert, 2004, 423-424). Rupert doubts that HEC can show an external functional equivalent of the generation effect displayed by internal memory wherein memorizing involves the use of associated pairs during both memorization and recall (2004, 424). He explains, "The generation effect consists in a mnemonic advantage reaped by subjects who generate their own meaningful connections between pieces of material to be learned" (2004, 416). Notebooks do not generate associations. Rupert elaborates that even if a generation effect were to appear by using external resources, this would be entirely optional, which is not the case for internal memory. For example, if the subject completely externalized the whole process of writing out all generated and non-generated context sentences, there would be no generation effect in this case (Rupert, 2004, 417-418). Along the same lines, Rupert does not see the possibility of HEC finding the internal functional equivalency of learning and forgetting with regard to external memory (2004, 425). Otto's notebook is not subjected to functional equivalencies of either the generation effect or the effects of learning and forgetting, since its contents are preserved and as accurate as when they were originally written. By contrast, Inga's internal memory relies on associations and is subject to fallibility when it comes to remembering. Rupert adds that although Clark and Chalmers see the explanation of Otto having to remember to remember to consult his notebook as unnecessarily complex, Rupert asserts such an explanation would show how external memory does not display the generation effect, or internally functionally equivalent instances of learning and forgetting (2004, 424-426). Thus, Rupert contends that HEC's functionalism, grounded in "empirically productive service", is not a good prospect as a psycho-functional account since the explanatory kinds such as internal memory currently described by cognitive science do not have realizations with external components (2004, 423).

2.2.3.1 Cognitive Bloat

Mark Rowlands describes cognitive bloat as "the admission of extended cognitive processes in which our conception of the cognitive will become too permissive, placing us on a slippery slope of being forced to admit into the category of the cognitive all sorts of structures and processes that are obviously not cognitive (2009, 2). Similarly, Robert Rupert explains that cognitive bloat is a problematic side effect resulting from characterizing generic kinds in order to have external instances, thus reducing their causal-explanatory power (2013, 30). He maintains that his library and telephone directory examples display potential instances of cognitive bloat (Rupert, 2004, 403, 421). That is, since the man in the library has at one point done what the HEC theorist claims amounts to consciously endorsing the content of the books he has read, then all of the information in the books would be classified as part of his external memory (Rupert 2004, 421). Regarding his telephone directory assistance example, Rupert insists, “It is absurd to say that Otto has *beliefs* about all of the phone numbers available to him through directory assistance (that is, *beliefs* of the form, ‘John Doe's phone number is ###-####’), so long as he remembers how to dial up the operator” (2004, 403 italics added). The notion of belief used in the telephone directory example is a radical departure from its ordinary usage, in the same way in which we would not say that Otto “knows” the phone numbers (Rupert, 2004, 403). Rupert maintains that while Clark and Chalmers’ requirement of past conscious endorsement is well advised, he has shown how it is insufficient for explaining the boundary conditions for what are considered as cognitive processes (2004, 404).

Rowlands remarks that Clark and Chalmers’ conscious past endorsement criterion on beliefs is an effort to try to preclude the problem of bloat (2009, 6). For example, the entries in Otto’s notebook are admitted as beliefs due to conscious past endorsement and the “sufficiently and relevantly similar” functional role played by the beliefs of Inga (Rowlands, 2009, 6). From this perspective, the entries in Otto’s phone directory do not count as beliefs since they have not been at some point consciously endorsed (Rowlands, 2009, 6).

2.2.3.2 Boundary Issues

Rupert argues that there are boundary issues for the empirical functionalist view, specifically regarding cognitive science research into artificial intelligence (AI) and developmental psychology (2004, 425-428; 2010, 332-334). Rupert claims that HEC is incompatible with AI research developments in cognitive science due to self-contained nature of artificial intelligence (2004, 426). He explains that in order for HEC to apply in the case of an AI, the environment would need to be considered as part of the system and would have to travel along with the artificial intelligence, making the AI unnecessarily complex (Rupert, 2004, 426). AI intelligent systems are largely self-contained units that can function in various environments and putting more of the environment into these units would their flexibility, making it difficult to see the intelligence advantage of such an extended system (Rupert, 2004, 426).

Rupert claims that the way skills are learned according to developmental psychology, poses a boundary problem for HEC theorists (2004, 426). He states that skills which are acquired by a system over the course of its development are confined to a theoretical account of the skills of a single coherent system (Rupert, 2004, 426). Rupert explains that the typical developmental process involves dispensable and variable external artefacts which are not necessarily parts of an integrated system that persists over time, for example, the floor that one learns to walk on as a child is not present now yet the present floor plays a similar role (2004, 426). This causes problems for the functionalist theory in that the functionalist must look to empirical work to tell which systems apply, and yet their theory does not give licence to include the present floor in part of the overall cognitive system (Rupert, 2004, 427). A dilemma emerges for the developmental theorist in that she must be able to account for the flexibility of skills acquired by a system over the course of its development but she is limited to describing those skills in a way that both includes extended systems and allows for component replacement of external elements while preserving their functional structural role, giving up flexibility (Rupert, 2004, 428).

Rupert insists that part of the problem is that HEC argues from the basis of empirical observations about language and cognition to the conclusion that the mind is extended, relying on an unreliable form of inference (2010, 325). He explains that this type of reasoning maintains that “if a thought (or mental activity, or cognition) depends on factor X in some especially strong or clear way, then X is literally part of the thinker’s cognitive system“(Rupert, 2010, 326). This is particularly problematic when applied to developmental psychology and persisting individual human systems, since individuals form thousands of “systems” with external artefacts over time (Rupert, 2010, 330). The HEC theorist’s appeal to dependence reasoning suggests a reconceptualising of developmental psychology. That is, to call the external factors “cognitive” seems to be an exercise in relabeling of them rather than what cognitive science does which is to *explore* persisting organismic system interactions with extra organismic factors (Rupert, 2010, 333-334). Rupert contends that this relabeling of external materials as cognitive over-complicates matters, and “introduces an inflated set of distinct cognitive systems, then partitions them into useful sets – merely reproducing the structure of the orthodox cognitive system” (2010, 334). He concludes that HEMC is better at articulating the important difference between the skills acquired and the later application of those skills since it does not have to account for the extended mental states and systems in the way that HEC does (Rupert, 2004, 428). Based on an appeal to simplicity cognitive science is better off staying with its traditional taxonomy, that of HEMC (Rupert, 2010, 334).

2.2.4 HEC or HEMC?

Rupert concludes that Clark and Chalmers do not prove any cognitive goings on outside the head and that their theory supports HEMC not HEC (2004, 2013). He argues that the intuitive argument fails due to the requirement of conscious endorsement, while the natural kinds argument fails to do any powerful causal explanatory work due to what Rupert determines to be a false premise in Clark and Chalmers’ argument, “the [premise] claiming that a HEC friendly taxonomy provides a more powerful framework for cognitive psychology” (Rupert, 2009, 6). Rupert also shows that the empirical functionalist basis for HEC merely adds a complicated taxonomical layer in cognitive science research, specifically in the areas of artificial intelligence and developmental psychology.

Rupert maintains that while Clark and Chalmers think they are arguing for HEC, (cognitive states or processes extended beyond the body), their arguments support only HEMC, (an interactively organism-bound cognitive system). Clark states that both hypotheses claim cognitive processing depends in some complex way, on the organism's use of external resources (2010b, 1059). As well, Clark notes that while both HEC and HEMC can accommodate experiments and empirical data, it is "considerations of conservatives and fit with the existing cognitive psychological tradition" that are argued for (2010b, 1058). What is at stake in this debate about cognition outside the head is not an accurate description of the outer behaviours of many Ottos and their notebooks, but a theory of cognition and mind extension that argues for what is going on undercover. That is, while the external behavioural picture looks the same to both Rupert and Clark & Chalmers, which is a human organism using external artefacts to aid cognition, they argue about what is going on behind the scenes at the cognitive processing level or where the cognitive processes are situated (Clark, 2010b, 1059). While Clark sees Rupert's preference for HEMC making sense in terms of an appeal to "persisting integrated systems" as objects of study, existing practice and accommodation of newer perspectives, Clark argues that preference for HEMC over HEC is an unduly restrictive and premature claim in terms of emerging work in cognitive science and cognitive psychology (2010b, 1059). Instead, Clark recommends we "carve our cake in several different ways for varying experimental and theoretical purposes" (2010b, 1059). If the goal is to understand the cognizing that can be done by a biological organism alone, then HEMC will do (Clark, 2010b, 1059). However, if the goal is to "understand the cognizing that a person (a socially and technologically situated entity) can do, we may need to study the class of systems that includes loops through the body and world", which is HEC (Clark, 2010b, 1059). For example, if we restrict ourselves to a HEMC view, then we might restrict external aids to "counting on fingers but not the use of notepads" (Clark 2010b, 1059). Clark's (2008) extended system example of Ada the accountant serves as an exemplar of the underlying problem that is really at stake in the Rupert-Clark and Chalmers debate and will be examined more closely. The example shows how Ada deploys external resources to augment her internal memory when solving accounting problems. Ada's cognitive processing is broken down step by step, demonstrating the intricacy of the integration of resources, making it difficult to challenge the functional equivalency of internal and external resources.

2.2.4.1 Extended system example: Ada the accountant

Clark's example of Ada the Accountant outlines a scenario that depicts internal and external memory in action (2008, 69-71). In this example, Clark advocates "an image of the local mechanisms of human cognition quite literally bleeding out into the body and the world", rejecting "the image of the mind as a kind of input-output sandwich with cognition as the filling" (2008, 70). Ada is adept at dealing with long tables of figures, and has developed superior problem determination skills when it comes to solving specific classes of accounting problems. She uses a paper scratchpad to copy numbers she has scanned from long columns of figures, and refers back and forth between the scratchpad and the columns of data. Clark notes that Ada is said to be deploying "minimal memory strategies" by using the scratchpad instead of committing huge amounts of data to her biological short-term memory (2008, 69). Throughout the problem-solving stage, Ada creates and cross references marks or trails of numbers on the scratch pad, which she refers to in a just-in-time (JIT), need-to-know basis, and these numbers are briefly loaded into her short-term memory for use in computations.

Clark compares Ada's behaviour to the way in which a serial computer uses its registers for computation (2008, 71). He summarizes the Ada example as an "extended process" that can be "analyzed in familiar terms as a set of problem-solving state transitions whose implementation happens to involve a distributed combination of biological memory, motor actions, external symbolic storage, and just-in-time perceptual access" (Clark, 2008, 69). While what Clark describes as an "extended process" fits his image of cognition in the world, his serial computing comparison could be taken further towards eliminating the possibility of the mind being a "cognitive sandwich". An appeal to system theory helps to explain Ada's integral role in the overall system. Within John Haugeland's (1998) characterization of a system, Ada's processing could be seen as a relevant interacting component of a larger system that begins with the problem and ends with its resolution (or at least some output). Haugeland defines a system as "a relatively independent and self-contained composite of components interacting at interfaces" (1998, 213). Components are "relatively independent and self-contained" portions of a system that relevantly interact with other components only through interfaces between them (Haugeland, 1998, 213). An interface is "a point of interactive 'contact' between relatively independent and self-contained composite components such that the relevant interactions are well-defined, reliable, and relatively simple" (Haugeland, 1998, 213). Under this definition, Ada's processing is a problem-solving *component* in the system. Ada's work is more than just an interim calculation; she is an integral component of the system. Even though she takes in the information, uses the scratchpad, and produces output, Ada provides another key piece to the system that could not be achieved with a mere calculating device or a non-accountant. That is, Ada knows what to do with the data. By using her extensive knowledge of accounting principles, Ada is able to distinguish between for instance, good and bad data. The reason she is able to solve the problem on her own using the scratchpad method in the first place is that she has developed problem determination and resolution skills based on her years of expertise in her field. Ada is not only calculating and comparing data, she is applying her knowledge when making decisions about each piece of data.

A process is just one element within the larger scope of a system, and is typically designed as a ‘compute and output’ of the information provided, with the output of the process used elsewhere within the system. The interim calculations are not required for the output of the system. In other words, the system is not obliged to ‘show its work’ in the same way as a math student. The process part involves the use of the external symbolic storage (the scratch pad) and the JIT access used to solve the problem (the output). There can be many processes within a system in order to get a result. Had Ada scanned each column of the data independently, each having its own scratch pad, then Ada would be considered a component doing the same repetitive process. The result would be the same, but this system would have as many processes as there are columns of data.

The processing that Ada does functions in the same way as does the program’s temporary storage in a computation. The information is used in working or temporary storage (Ada’s paper scratch pad) and then disposed of once a result is achieved. It is this result that is pertinent to the system, not the interim process that calculates it. If the interim data was required later on, it would be committed to memory for later retrieval. Ada does not commit her paper scratchpad information to memory and so the paper acts merely as an auxiliary for her internal working storage or short term memory, not her long term memory. This can be contrasted with how Otto’s notebook functions in that the notebook is a substitute for his overall internal memory because the information is actually stored on the paper and not in his head. His notebook is not meant to serve as a scratch pad, but as a container of information for future use. Transient information in working or temporary storage does not qualify as knowledge in the same way as does committing to a belief. When Otto enters the information in his notebook, he is using the notebook as memory, and the information remains stable and intact with a pointer to it in his mind. In summary, the example shows how Ada is a crucial component of a cognitive system with processes looping through her brain and environment. There is little dispute that Ada is engaging in a specific cognitive process when she is manipulating her accounting numbers. The specific cognitive process that uses the pen and paper can be seen as constituted by pen, paper, hand, eye and neuro circuits. Ada writes down an entry and at some point later in time, references that entry. Likewise Otto writes down an entry and later references it. It is easier to conceive the constituents of a rapid process as being part of that process, but in a formal sense Ada and Otto are doing the same thing, namely writing an entry and referring to it at a later point in time to guide a subsequent action.

2.3 Conclusion

2.3.1 Adams and Aizawa

Frederick Adams and Kenneth Aizawa provide a useful description of what they believe to be five types of arguments for HEC, the first three of which have been addressed in this chapter in terms of their direct relation to the three distinctions discussed regarding coupling, constitution and the mark of the cognitive (2008, 10-11). The remaining two types of arguments for extended mind surface as second wave arguments. These are, first, the “complementarity arguments” in which cognitive equivalence is supposed because brain and environment work well together, and second, the type of argument that appeals to the theory of evolution in which humans have adapted and incorporated external artefacts into their cognitive realm such that there is continued reliance upon that environmental feature (Adams and Aizawa, 2008, 10-11). The complementarity argument type will be expanded upon in the next chapter in the form of John Sutton's (2010) complementarity principle. The argument from evolution and culture will be elaborated upon by way of Merlin Donald's (1999, 2001) mimesis theory and Mark Rowlands' (1999, 2011) notion of hybrid memory.

2.3.2 Rupert

Robert Rupert's HEC challenges of the intuitive argument dilemma, natural kinds issues, and functionalism concerns have been addressed in this chapter. The next chapter will continue to address philosophical concerns over *parity*, in the form of John Sutton's (2010) complementarity principle, *integration* by way of Richard Menary's (2006) scaffolding theory, and *functionalism* in terms of Michael Wheeler's (2010) extended version and Mark Sprevak's (2010) coarse grained view.

2.3.3 EM and Memory

Clark and Chalmers' (1998) example involves the Alzheimer sufferer Otto storing memories in his notebook. Clark's (2008) example involves the accountant Ada operating in a way in which internal and external memory work together. Yet Rupert (2004) uses memory as a base cognitive trait in his arguments against cognitive extension and argues against possible functional equivalency for external memory with internal memory in the areas of memory formation, learning and forgetting, and the generation effect. Finally, Adams and Aizawa (2008) challenge the criteria for the cognitive status of external information with Rowlands (2009) responding using an example of externally stored memory.

The trend of using memory as a basis for Extended Mind continues with second wave arguments, which are covered in the next chapter.

2.4 Section Summary

In this section I have demonstrated that while the claims of functional parity and past endorsement are sufficient to establish that an external artefact can act as a memory supplement, these arguments fail to overcome the objections to the claim of mind extension.

CHAPTER 3 SECOND WAVE EM: COMPLEMENTARITY

The purpose of this section is to show how second wave arguments for Extended Mind provide a more promising explanation of mind extension. Complementarity, scaffolding and integration explore the pairings of internal and external elements based on the coordination of such resources. These views broaden the scope of Extended Mind by explaining how other minds as well as artefacts can be external resources.

This chapter will show how the focus of first wave Extended Mind arguments on parity and functionalism is augmented with, and in some cases supplanted by, second wave arguments from complementarity wherein external resources are co-opted to form dynamic couplings between cognitive agent and environment. Memory was used as a base cognitive trait in Extended Mind arguments and this trend is also found in complementarity arguments. This chapter will make it evident that Extended Mind and complementarity arguments for extended memory are less controversial than overall mind extension.

We begin with an explanation of complementarity and the problems with parity that it seeks to resolve. Next, we present co-operative complementarity approaches to Extended Mind, which are those that preserve some form of functionalism while at the same time honouring differences in external resources and focussing on the individual. The following section addresses complementarity in the form of other minds acting as external resources for each other. Different types of group memory are described in sufficient detail so they can be distinguished and the model in Chapter 5 can be tested against them. The last section explores complementarity and technology, outlining what this means for individual and group memory.

3.1 The Complementarity Principle

John Sutton distinguishes between first and second wave EM explanations based on how each line of thought accounts for the contributions of external artefacts in the overall extended cognitive system (2010, 193). The first wave explanations are based on Clark and Chalmers' (1998) *parity principle* claim that admits wide cognitive processing. Sutton's interpretation of the parity principle is, "If 'exograms' *act* as engrams do, then for explanatory purposes they can be treated as engrams, the difference in their location being entirely superficial" (2010, 194, italics his). Engrams are the brain's neural memory traces, and Merlin Donald coined the analogous word exogram "to describe the external symbols which we as a species have come to combine, manipulate, and rely on" (Sutton, 2013, 8).

The second wave explanations are based on a *complementarity principle,* which Sutton explains in this way: "In extended cognitive systems, external states and processes need not mimic or replicate the formats, dynamics, or functions of inner states and processes. Rather, different components of the overall (enduring or temporary) system can play quite different roles and have different properties while coupling in collective and complementary contributions to flexible thinking and acting" (2010, 194). Complementarity widens the scope of study regarding how agents interact with their environments. While EMH parity focuses on generic features of cognitive states and processes, making it useful for studying one agent with a specific artefact, complementarity admits the study of one agent interactively and fluidly moving between artifacts (Sutton, 2010, 199). That is, with respect to the complementarity approach, the focus is not on how alike internal and external resources are, but on the exploitation of the differences between artifacts. Complementarity offers an explanatory means for ways in which agents use external artefacts in a cooperative manner contributing to the enhancement of cognitive features. Further, Sutton states that the status of exograms in complementarity-oriented explanations can be radically different than engrams even when serving the same purpose, and it is these differences that will be the focus of explanations (2010, 194). For example, Inga could use a notebook to store details such as a bus schedule, her friend's telephone number or Otto's medication dosage and timetable, all serving as supportive information she might need for her MoMA excursion.

As will be shown in this chapter, complementarity arguments are not subject to the same objections faced by arguments based on parity. Not only are second wave explanations compatible with the first wave explanations of parity, complementarity provides "natural answers to a number of objections to EM which spring from parity considerations" (Sutton, 2010, 194). In the next section, I draw upon Sutton's arguments to elucidate problems with parity, for instance, since parity focuses on the similarity of resources, the argument is open to criticisms regarding any differences between inner and outer processes. On the other hand, complementarity emphasizes the use of external resources as supplemental based on their differences.

3.1.1 Problems with Parity

Sutton explains that while Clark and Chalmers' parity principle admits Otto's notebook as playing a cognitive role when in use, the principle also puts forth the stronger claim that the notebook counts as cognitive since the standing information it contains functions in a similar manner to Inga's beliefs and memories. This is because Otto's past endorsement of the contents of the notebook and its reliability and consistency are said to mirror the role of Inga's internal memory (Sutton, 2010, 195). Sutton claims the first significant problem for parity emerges as a result of the natural application of parity considerations to cases such as Otto and Inga, since some individualists, such as F. Adams and K. Aizawa (2008), challenge Otto's additional requirement of the use of motor and visual processes (2010, 196). For example, Adams and Aizawa (2008, 2010) raise an objection which has come to be known as the "Otto two step" (a term used by Clark, 2010a, 46). Their challenge is that while Inga's recall is seamless, Otto has to have the desire to go to the museum, then consult his notebook, and Otto's two-step approach introduces unnecessary complexity (2008, 24-25). Clark responds to the Otto two-step objection to Inga and Otto by emphasizing that Otto's notebook is "fluently deployed" (2010b, 1048) as is Inga's memory, and both act in the same way. But Clark's explanation is too lean for some philosophers. For instance, Richard Menary claims that Clark misses this point of the objection (2010, 10). Menary emphasizes that we don't normally have to remember that we remember something, as in the notebook (2010, 10). However Menary's challenge of having to remembering the location of a memory, misses Clark's point in that it is not that there are *two beliefs* at stake; it is the notion of an "extended belief" across *two media*, which are Otto's notebook and his brain. The notebook acts as more than external storage; it is a privileged, marked, personalized form of storage, which for Clark and Chalmers conforms to the parity principle. Sutton notes this type of challenge unrealistically pushes the parity principle too far, to the point at which EM is refuted based on any difference at all between inner and outer states and processes (2010, 196). Sutton's view echoes Clark's response, which is that parity does not require that internal and external processes be identical, only that they are functionally similar and subject to the same reliability and transparency considerations (2010, 197).

Sutton outlines another significant problem for parity-based theories, concerning cases where parity overlooks "significant differences in format and dynamics between engrams and exograms" (2010, 197). He explains that by focusing on the role of the resources, the parity principle does not encourage attention to the distinct features of the components, and this inattention to differences between the natures of cognitive artifacts overlooks the potential study of particular features and peculiarities of exograms or ways of interfacing with them (Sutton, 2010, 198-200). Complementarity both acknowledges and welcomes such differences. Cognitive anthropologists, developmental psychologists, sociologists and historians are interested in the ways in which our brains, behaviour and cognitive structure are affected by our co-opting of cognitive artifacts, and the parity principle does not engage with cognitive couplings in terms of differences between the artifacts (Sutton, 2010, 198). Whereas psychologists typically study differences in the ways that individuals approach cognitive tasks without the use of external artifacts, the way in which individuals engage with external resources offers an opportunity for a multidisciplinary approach to understanding behaviour. Which external resources we use and when we use them could provide psychological insights into the ways in which individuals handle engage in complex activities (2010, 199).

3.2 Co-operative Complementarity and Individual Memory

The complementarity principle is useful in justifying cognitive psychology’s interest in the brain and environment rather than being restricted to what goes on in the head (John Sutton, Celia Harris, Paul Keil and Amanda Barnier, 2010, 11). The appeal to complementarity highlights that the claim is for extended mind, not that artefacts are independent thinking things, since these external things do not display cognitive processes independently of being engaged in a cognitive system of activity (Sutton et al., 2010, 4-7).

Sutton emphasizes that the mind need not “replicate” external capacities since interfacing with them as complementary resources makes more sense (2010, 205). He notes that Clark (1997) considered external artefacts as supplemental, with emphasis on the way they work together in the overall system of thought and action. Emphasis on co-operative complementarity with respect to individual plus artefact memory extension lies at the heart of both Clark's and other writers' theories about EM, including Michael Wheeler's (2010) form of extended functionalism, Richard Menary's (2006) integrationist approach and Mark Rowlands' (1999, 2009, 2011) environmentalism. These views will next be discussed in turn.

3.2.1 Extended Functionalism: The case for generic memory

Michael Wheeler (2010) puts forth an extended functionalist view of extended cognition which encompasses the idea that not all elements outside the head require cognitive status in order to be part of a larger cognitive system. This broader version of functionalism goes beyond the limits of the parity principle and is compatible with a complementarity approach to cognitive extension since mental states or their equivalents are not requited in external elements.

Wheeler describes the more traditional view of functionalism as upholding that "a mental state counts as the mental state it does because of the causal relations it bears to sensory inputs, behavioural inputs, and other mental states" (2010, 247). He adds that what the psychologically relevant casual relations are is a matter of intellectual debate between philosophical conceptual analysis and psychological experiment (2010, 247). Wheeler goes on to explain that functionalism is intended to free us from chauvinism about the mind by way of its property of *multiple realizability,* which holds that since their causal-functional roles are what constitute psychological phenomena, terms such as *mental states* and *mental processes* "pick out equivalence classes of different material substrates" (2010, 248). Building on this traditional view, Wheeler explains a more general characterization of functionalism, one that will allow for an extended view that goes beyond the brain and body. Under this wider form of functionalism, a "systemic state" is a mental state constituted by its causal relations. He states, "What makes a systemic state a mental state is the set of causal relations that it bears to systemic inputs, systemic outputs, and other systemic states" (2010, 248).

Wheeler's view combines functional equality of properly causally arranged internal and external elements included in extended cognition, with the multiple realizability of type-identified generic cognitive processes in two forms, inner and external, to yield an *extended functionalism* (Wheeler, 2010, 248-249). The multiple realizability characteristic of extended functionalism eliminates chauvinism of mind and allows, in principle, for appropriately functionally organized Martians, robots and other beings to have mental states (Wheeler, 2010, 247-248). Wheeler's argument for extended functionalism is demonstrated in his answers to possible objections from Adams and Aizawa (2008), Robert Rupert (2004) and Mark Sprevak (2009), which will be addressed in turn.

3.2.1.1 Multiple realizability and functionalism

Wheeler characterizes Adams and Aizawa's objection to extended cognition as being grounded in their expectation of "processes as distinct as cognitive processes to be realized by distinctive lower-level processes" (2010, 249). Under their view, only neuronal states and processes qualify as vehicles for cognition since, as Adams and Aizawa admit, their materialist views advocate the belief "that all cognitive processes are in some sense determined by lower-level biological, chemical, or physical processes" (2008, 68). They suggest that only neurons process information in ways that enable cognition, and acknowledge that this view is contrary to functionalist views which claim that, in principle, many things could be organized to form a cognitive processor (Adams and Aizawa, 2008, 68-69). Appealing to an example in human biology to strengthen their case, Adams and Aizawa point out that while muscles and organs are made up of cells, particular types of cell can have radically different cellular structure. For instance, liver cells and muscle cells are not interchangeable since the former type helps to regulate, synthesize and store substances in the body, while the latter contain the necessary fibres to shorten and lengthen in support of muscle contraction. According to individualists, since cognitive processes are distinctive and not spread beyond the brain into space, the expectation is that these processes would "supervene on correspondingly distinct lower-level processes" (Adams and Aizawa, 2008, 68).

Wheeler counters this argument with an appeal to functional convergence in evolution, wherein two or more biological entities perform the same function. For example, the way in which humans (and many other animals) and fruit flies break down alcohols is vastly different in terms of the *sequence and structure* of enzymes, yet both beings use the same *type* of enzymes to do so. Vertebrates and fruit flies use the same enzymes to break down alcohol, however, the enzyme sequences and chemical reactions are different. Wheeler claims this type of processing displays multiple realizability of the enzyme, which is a distinctive higher-level phenomenon (2010, 250-251). Wheeler argues that what Adams and Aizawa are actually raising is an issue of the "range" of what admits as cognitive processing, which amounts to a rejection of multiple realizability, not extended cognition. This is because Adams and Aizawa confuse cognitive processing with the lower-level individual cognitive processes (2010, 250). Wheeler maintains that Adams and Aizawa do not necessarily object to the outer mimicking the inner, but to the idea that the mind itself is said to extend. So the door for extended functionalism remains open (2010, 251).

3.2.1.2 The Rowlands' Deadlock

Wheeler addresses a more nuanced objection, which starts with Rupert's (2004) argument against cognitive extension and leads to what Wheeler labels the *Rowlands deadlock*. The formulation of the deadlock is based on pitting Rupert's challenge to the cognitive trait of memory and applying the results to cognition in general against Wheeler's response as a result of the functionalist terms of the debate. The deadlock involves Wheeler's accusation against Rupert of question-begging by way of presupposing a chauvinistic form of functionalism, and Rupert's challenge that extended mind arguments could be accused of question-begging by advocating a liberal form of functionalism in the first place (Wheeler, 2010, 255).

Wheeler claims that Robert Rupert's (2004, 416-426) argument that memory formation, learning, forgetting, and the generation effect must be accommodated by externally functionally equivalent mental states, is flawed in that he privileges the inner as a benchmark for parity, and the memory characteristics Rupert appeals to are not defining features of memory (2010, 253-256). According to Wheeler, Rupert's argument is structured in such a way as to begin with an internal feature of a core cognitive trait such as the generation effect of memory, then to show how this trait is not shared in the proper way by any extended cognitive system, and to conclude that since the parity principle is not satisfied, then HEC is false (2010, 252). The challenge begins with Rupert claiming internal memory uniqueness and superiority based on the generation effect wherein internal memory has a mnemonic association-building natural advantage that can only occur internally. Under this view, external memory is not possible since it is not privy to this internal association building. Rupert admits that although there may be small instances of mnemonic associations using a notebook, these are too few and too shallow to qualify along the same standards as internal processing (2004, 402-403, 418-421).

Wheeler answers Rupert's objection by arguing that even if there are functional differences between internal and external memory, the parity principle is at risk of breaking down only if the inner is the privileged benchmark, which would be dually problematic since this in turn would re-introduce chauvinism into the philosophy of mind, something functionalism had negated (2010, 255). He further argues that to begin with a cognitive system that includes outer elements, and then to privilege the inner, amounts to location-bias. Wheeler explains that by seeking to "characterize functionally" the traits of memory, Rupert sees cognitive science as a functionalist enterprise. He accuses Rupert of question-begging against extended functionalism because Rupert's argument takes cognitive science to be broadly based in a chauvinistic form of functionalism by benchmarking based on the inner. Due to this focus on the traits of memory, by *cognitive science*, Rupert means "*conventional human-oriented and inner-oriented cognitive psychology*" (2010, 255). However, extended functionalism is not affected by Rupert's chauvinistic form of functionalism because extended functionalism is locationally neutral. It is the granularity of the inner, not the multiple realizability of extended functionalism, which contributes to the cognitive processing (Wheeler, 2010, 255).

Wheeler explains a way out of the deadlock that favours extended cognition, which is the case for generic memory. He accuses Rupert of generalizing what applies to memory to cognition, going from the generation effect of internal memory to cognition in general, and this is problematic in that Rupert's case is for this one characteristic of internal memory, which itself is not a defining feature of memory (2010, 256). For example, Wheeler asks us to suppose there is a human whose inner memory doesn't display the generation effect yet displays other memory traits such as "context-sensitive selective storage and retrieval of information". In this scenario cognitive psychologists would find a functional difference between such a person and a "normal" human subject, but would not say the non-generation effect subject lacks the cognitive trait of memory (2010, 256). Since the affected person still has memory, what we have is a case for an explanatorily useful account of generic memory that is "broad enough to cover generation-effect and non-generation effect causes" (2010, 256). That cognitive psychologists would investigate a subject who doesn't display the generation effect grants explanatory credentials for generic memory, thus making it a useful explanatory form of cognitive state (2010, 258). Furthermore, this line of thinking could be applied beyond memory to other forms of cognition such as inference, for instance, the gambler's fallacy, a mistaken belief that random occurrences are influenced by previous occurrences, for example, flipping a coin (Wheeler, 2010, 257). Generic memory is a way out of the Rowlands deadlock in favour of extended functionalism.

3.2.1.3 Martian Intuition

The third possible objection Wheeler addresses is from Mark Sprevak. Sprevak (2009) claims that HEC entails functionalism and that the active externalism proposed by extended mind proponents pushes functionalism so far as to form its own counterexample. Sprevak explains that the problem stems from the combination of HEC's functionalism and the extra conditions of past endorsement that make HEC more modest and plausible. That is, part of the HEC claim is that in lieu of parity and past endorsement conditions, although external processes are not exactly the same as internal ones, these processes are classed as cognitive all the same. Sprevak argues that these extra conditions are incompatible with what he labels HEC's "functionalist defence" since the admission of external processes requires such a radical form of functionalism that it ends up forming its own counterexample (2009, 1, 10). Sprevak's example of Martian Intuition elaborates on his challenge. He asks us to suppose there is a Martian whose internal make up is different than that of a human who still has mental states and cognitive processes, since there is no reason to think that mentality has to involve a human-like nervous system, neural processes and DNA (2009, 4). Reminding us that HEC draws its functional granularity boundary wide enough to include Otto's notebook, Sprevak argues that HEC's functionalist account would also be coarse-grained enough to allow for cognizing Martians. This is because, for HEC, the location does not matter and the internal and external are treated at par based on functional equivalence. Based on what Sprevak calls a *fair treatment principle*, HEC's functionalism and parity conditions would have to admit cognitive status to both internal and external non-typically invoked and non-reliably available processes (2009, 10). That is, for HEC's functionalist argument to work, fair treatment must be granted to inner and outer resources. However, fair treatment and radical functionalism lead to over-permissiveness in attributing mental states, making HEC-based functionalism unpalatable as a theory of extended cognition since the degree of functionalism it requires is so radical that it leads to false consequences (2009, 14, 16). For example, just by picking up a book, a person could be said to believe everything contained in its pages. This is because, as Sprevak explains, it could be imagined that a Martian who encodes her beliefs using ink marks in her head goes through a developmental process of activating innate beliefs. The difference between the human and the Martian is the location of the ink blots, which are either inside or outside the head. If he Martian is said to have the beliefs, then by fair treatment so does the human (2009, 14). A second example is to imagine a Martian with the internal cognitive processes necessary to calculate the Mayan calendar, then by fair treatment I also have those cognitive processes (2009, 12). The way this is justified is that if for instance I use a desktop computer to calculate the Mayan calendar, and the Martian does the same calculation without using a computer, then according to radical functionalism I possess a mental process that does this calculation (2009, 14-16). Sprevak reasons that based on this example, it can be said that the process the computer performs is a mental process possessed by the human (2009, 16). This is because HEC's coarse grained functionalism admits cognitive status to the system composed of human and computer and the Martian can perform the same calculation by using only internal processes.

Wheeler explains an additional consequence in that if Sprevak's Martian can perform the difficult calculation of the Mayan calendar and a computer can do the same, then under coarse-grained functionalism and the parity principle, the computer is as cognitive as a human. However, Wheeler sees the admission of a desktop computer as intuitively wrong in that although the desktop process is a potential aid to my cognition, the computer itself is "not part of my cognitive architecture" (2010, 262). Sprevak's method is to outline a radical case in which a human requires an external aid such as a computer in order to cognitively process something a Martian can do without a computer, then to claim that the human is said to mentally possess the processing done by the computer. Sprevak provides examples of a coarse grained functionalism that are so wide as to admit false consequences such as a human possessing computer processes as mental processes.

Wheeler states that Sprevak sets up a dilemma for both HEC and extended functionalism in that on the one hand, if radical functionalism entails a false theory, then functionalism itself is false, while on the other hand, we cannot give up the independently plausible Martian intuition or the parity principle (2010, 262). He breaks down Sprevak's argument in terms of three factors which are the functionalist view of HEC, the independent plausibility of Martian intuition, and the parity principle. He next outlines four steps to the dilemma: first, introduce a distributed example for HEC; second, add a functionally identical system under the Martian intuition; third, claim cognitive status for this system as per the parity principle; and fourth, reach anti-HEC and anti-extended functionalism conclusions (Wheeler, 2010, 262). Wheeler explains that the dilemma arises because of a Martian *sleight of mind* that occurs when Sprevak takes away the non-cognitive externally located elements in a distributed process and awards them cognitive status by moving them in the head, then invokes the fair treatment principle for the in the head processes, yet only the location has changed (2010, 263). What Sprevak has done is to move a process inside the head, making the non-cognitive into cognitive and then claim parity. That is, with the original Martian, cognition was *extended*, yet the Mayan calendar ability went totally *internal*, (step 2) thereby modifying the cognizing Martian to an unacceptable extreme, and in the process losing his claim to cognitive extension status and giving up plausibility. In other words, by adding the ability to perform this complicated computation to the Martian's repertoire, Sprevak sacrifices the Martian's claim to cognitive extension of this particular process. If the Mayan calendar calculation requires a computer then the process is extended. If, originally, the Martian is able to perform the calculation internally then the Mayan calendar ability is not a form of cognitive extension, but neither is the process necessarily cognitive. Wheeler notes that an additional problem for Martian intuition is that the posited Martian does not necessarily allow for everything that goes on in his head to qualify as cognitive; just because something goes on in the Martian head, does not mean it is cognitive (2010, 264). Wheeler concludes that the way to avoid the Sprevak dilemma is to refuse to endorse this move to the radical form of Martian intuition (2010, 264).

3.2.2 Manipulation and Environmentalism: The case for hybrid memory

Mark Rowlands' view is compatible with the complementarity principle in that it honours the differences between internal and external resources, and at the same time it attempts to preserve EM parity in the form of external cognitive processing status. Parity is achieved by way of adherence to Rowlands' *criterion of the cognitive* (2009, 4). The broadly understood function of cognition is to make previously unavailable information available in combination with other similar processes. These processes produce representational states and always belong to someone or something (2009, 15).

Rowlands seeks to "un-seat" the internalist picture in favour of a hybrid cognitive theory. His environmentalism theory maintains that neither mental states nor cognitive processes are solely internal, and furthermore cannot be knowable solely by internal means (1999, 119). The stability and distinct structure of external structures are important features that enable cognitive accomplishments which are not achievable by inner processes alone (2009, 4). Rowlands' self-described *integrationist* interpretation of the EM parity principle involves the co-opting of external resources to augment internal cognitive deficits in order to facilitate, and in some cases to allow for, certain cognitive processing (2009, 3). He argues that the integrationist perspective emphasizes both the *similarities,* and more importantly, the *differences* between internal and external processes. He points out that these differences are important because the use of external processes in the environment serves, for the most part, to enhance the capabilities of internal cognitive processes in that the agent can do things that she would not be able to accomplish using internal processes alone (2009, 3-4). For instance, using a calculator assists in large number crunching instead of having to rely solely on mental arithmetic. Rowlands cautions that integration alone is insufficient to establish analogous cognitive status for external resources. Cognitive status for external structures is dependent upon how these structures are *manipulated,* which is a process by which the external structures are used to make information available that was previously unavailable to the cognizing subject (2009, 13). Although it is coherent to think of mental processes as solely internal, Rowlands says the theoretical utility of this view needs to be challenged. He argues that we cannot possibly understand the nature of cognitive processes by restricting our focus to the internal (1999, 136). The manipulation of external-information-bearing structures involves a cognitive process since such manipulation is often essential to accomplish a cognitive task. Therefore manipulation of external-information-bearing structures is a cognitive process (1999, 137).

Rowlands describes Extended Mind (EM) theorists as attributing the label "cognitive" to the overall process, which includes "the hybrid combination of internal and external processes" (2011, 129). This is because the external processes involved are dependent on the internal ones for their cognitive status and it is only when the system is properly engaged that the "cognitive" label can be attributed to such a system (2011, 129). In other words, external processes are not cognitive unless they are combined with internal processes to form a cognitive system. He adds that external processes would be of no practical cognitive purpose without engaging with their internal counterparts (Rowlands, 2010, 88). Using memory as an example, Rowlands argues that some memory processes are not solely internal processes; they consist of interactions between a cognizing agent and her environment (1999, 119). External cues such as a string on a finger can serve as memory aids to remind us that we are to remember something, and this reminder is part of the process of remembering what the string refers to.

Rowlands' view is environmentalist because it focuses on what he calls a psychotectonic methodology, which examines what cognitive processes are necessary to build a mind. What he does throughout this constructive procedure is to take only what is necessary in the form of cognitive processes, assessing whether or not it needs to be confined to how much needs to be confined to the skull, and if so, how much of it has to be internal (1999, 119). If we begin with the processes, then location does not have to be a factor, at least not immediately. This provides the basis for Rowlands' proposed "hybrid" approach to mind, which means it is "made up of internal representations and operations defined over those representations together with physical manipulation of structures in the environment" (1999, 121). An external representation can be meaningful to a person as long as she has the key or code for a given set or symbols, and this code is presumably stored internally (1999, 142). For example, by going to a physical library and remembering the approximate location of the book, we are able to find the book on a shelf. Going to the appropriate section of the library is the key to unlocking or jogging our memory of the book's exact location and so finding the book is not purely an internal process. Some varieties of remembering are "hybrid", in that the external environment contains relevant information and the organism interacting and able to interpret this information (1999, 121). The external environment contains relevant information and the organism interacts and can interpret this information. Rowlands' hybrid view is compatible with the standard psychological taxonomy of memory. The next two sections explain some of this taxonomy.

3.2.2.1 Cues, traces and remembering

A typical psychological description of memory is that memory is a process of storing and retrieving information and experiences (Jackie Andrade and Jon May, 2004, 60). There are three interacting stages of remembering, which are encoding, storage and retrieval, and a well-encoded memory improves storage and retrieval processing (2004, 66). Human memory encoding involves "understanding, organizing and integrating incoming information" (Andrade and May, 2004, 66).

Remembering is accomplished via memory traces, which Endel Tulving and Michael Watkins define as, "change[s] in the memory system that results from the perception and encoding of an event" (1975, 261). The memory trace must be part of a bigger picture, defined in terms of the relation between "products and conditions of retrieval" (Tulving and Watkins, 1975, 262). Traces are not observable in themselves, and they must be described indirectly via things that can be observed, such as input, retrieval cue and output. To use stored information in memory, the information must be accessible, and "accessibility is governed by retrieval cues", which are aspects known at the beginning or become known during retrieval (Endel Tulving and Donald Thomson, 1971, 123). Furthermore, the effectiveness of a cue depends on its own encoding pattern and that of the stored information which can vary from one occasion to the next, even if it is the same item (Tulving and Thomson, 1971, 123). Similar items may be subject to different encoding due to differences in their cognitive environments (1971, 116). In their testing, Tulving and Thomson found that recall and recognition processing of certain words to be remembered varied according to the other words in the group. The context of encoding for the same items is affected by the surrounding context, in this case the other words in the group (1971, 123). In order to recall stored internal memory, the information must be accessible and much of this depends on context. For example, in cases where words are stored as paired associates, recognition is impaired if one member is removed (Tulving and Thomson, 1971, 121).

Rowlands maintains that it is easier that EM has external triggers and representations due to its situational-specific nature. However, the crispness and detailed accuracy in remembering these experiences eventually wanes, fading into a more descriptive than representational mode. For example, immediately following a trip to Disneyland I would be able to recount specific details of the setting and my activities each day. Years later I may not be able to recall the exact year of my vacation to Disneyland, and the trip as a whole is recounted as a narrative of a general experience. Rowlands explains, "Episodic memory is gradually transformed into semantic memory when its specific episodic or concrete experiential content becomes sufficiently abstract and attenuated that its situational specificity is lost" (1999, 126). As time passes we are able to describe our trip to Disneyland but without the specific details of each ride we took or attraction we visited. Semantic memory is a store of information about meaning and factual knowledge that a person possesses. Whereas episodic memory is about a specific event that occurred at a specific time and place, semantic memory store includes the abstracted concepts, rules and words stored in LTM, the context of acquisition long forgotten (Tulving, 1972, 386).

3.2.2.2 Memory storage and retrieval

The traditional model of memory structure consists of a division between Long Term Memory (LTM), and Short Term Memory (STM). The distinction between the two components is that immediate free recall yields items directly retrieved from a temporary STM, and items retrieved by retrieval cues are from the more durable storage in LTM (Richard Atkinson & Richard Shiffrin 1968, and N. C. Waugh & D. A. Norman 1965). LTM can be subdivided into procedural, episodic and semantic memory. Procedural or skill memory involves learnings that we have and use without having to consciously think about. Riding a bicycle is an example of using procedural memory in that it is not necessary to relearn skills such as how to pedal, balance and manoeuver the bike for each ride.

Endel Tulving (1972) made the distinction between episodic memory, which is recollection of an event, and semantic memory. The relationship between the two types is that episodic memory needs, and goes beyond, semantic memory. Episodic memory is developed after semantic memory in childhood. Tulving describes episodic memory as the type that allows us to reflect on personal experiences (1993, 67). This type of memory reflects the self-centeredness of the events remembered in that these are memories of our experiences from our point of view. Episodic memory is responsible for our ability to mentally time travel through our subjective past, present and future. Episodic memory requires activation for retrieval, a "retrieval mode", which can be either conscious or unconscious, but conscious awareness is required once it is retrieved so that we can know we are neither hallucinating nor dreaming, (Tulving, 1993, 67).

Rowlands claims that there are two types of storage and retrieval strategies for memory, which are internal biological in the brain and external non-biological (1999, 142). Rowlands uses the example of semantic memory as a basis for his argument that the functional architecture of modern memory is fundamentally different than of its predecessor, due to semantic and environmental cues, which caused a change in hardware involved in memory storage and retrieval. Episodic memory is transformed to semantic memory after a period of time in which the specific detail of the context of the event becomes blurred so that recounting the event becomes factual. Rowlands explains that the storage strategies of procedural or "how-to" memory involving learned actions and patterns, and episodic or concrete examples of the specific time, place and experiential element details of an event, are necessarily incompatible. He argues that since episodic occurrences are recalled in detail while procedural memories are non-specific and learned through practice, these memories could not all be stored in the same place or in the same way. Otherwise our memories would become overloaded with, for instance, all of our cycling experiences instead of just the learning of how to ride a bicycle. He explains that since each memory system stores different types of information, the storage strategies must be different. Procedural memory could not possibly work the way it does if it had to store the specifics of each situation. If all cycling experiences had to be stored in procedural memory, the procedural system would quickly become overloaded. Necessarily, the storage strategies of procedural and episodic memory systems are incompatible, since the same neural structure would have difficulty implementing both strategies. Therefore, Rowlands concludes, "it seems likely, two separate mechanisms evolved for two types of storage" (1999, 119). This line of argument also applies to semantic memory, the dominant form of memory in humans, which Rowlands argues is environment-evolving as well as biological. Semantic memory is hybrid because it “evolves” and uses structures in the environment (1999, 125). Rowlands claims that the sort of memory storage strategy that uses the environment is analogous to Merlin Donald’s (1991) notion of *networking*. Rowlands explains Donald’s networking notion to mean that both the hardware and software change when embedded in a network.

Merlin Donald claims that the way in which a computer network manipulates storage is analogous to how human memory adapts within a larger, external symbolic framework. The benefit of this analogy is that it shows how the hardware and software can change when embedded within a network. The hardware properties govern the memory size, central processing unit (CPU) and speed of processing, while the operating system and programming support are the software. When the analogy is applied to humans, the hardware is the neurophysiology and the software is the skills, language and knowledge. Donald’s central argument in *Origins of the Modern Mind* is “that very recent changes in the organization of the human mind are just as fundamental as those that took place in earlier evolutionary transitions, yet they are mediated by new memory technology, rather than by genetically encoded changes in the brain” (1991, 4). He refers to the biologically encapsulated mind as a Leibnizian “monad” or simple substance, because within an information network monads are mediated via dynamic connections to external symbolic systems, which serve as temporarily shared memory resources. Minds in networks operate as part of a larger shared resource. The demands on the system and the limitations of any given network component result in software or skills being found anywhere and everywhere in a system depending on the information flow, access and priorities at any given time (1991, 313). Donald's claim is that both the hardware and software change when a computer is embedded in a network (1991, 272). He maintains that this is a structural change because the network can delegate to other parts if single parts exceed their capacity. But although Random Access Memory (RAM) is a way of expanding memory, such expansion cannot go on indefinitely, so external hard storage is used. What Donald means is that internal memory can only be "upgraded" within the limitations of the hardware itself and so the system has to eventually resort to external sources that serve as traditional memory resources. This results in individual CPU's together using a set of memory hardware in a common memory system (1991, 272).

Referring to the evolution of the architecture of mind, Donald foreshadows the EMH supporting claim, "in any case, the individual mind has long since ceased to be definable in a meaningful way within its confining biological membrane" (1991, 359). Furthermore, he predictively states, "probably the principal remaining function of biological working memory is supporting the construction of an oral-narrative commentary in the behavioural process of taking notes and theorizing" (1991, 332). Biological memory is a "reservoir" of strategies for scanning and searching external storage symbols and current semantic content that assembles all of the resources into a coherent story (1991, 333).

While Donald's analogy is in general correct, adding extra memory is technically not as straightforward as plug-and-play. There are both hardware and software compatibility and limitation issues as to which type of memory or storage and how much can be applied to the current system. There is also a performance cost to retrieving externally stored information in that the CPU must send the request, find the information, and re-load it into working storage before reading it. Donald's networking preceded Clark and Chalmers' externalism; otherwise

Donald could have used the cataloguing, verification, retrieval and re-integration of externally stored information as paralleling the parity principle and past endorsement criteria. This is one example of how both Donald's networking analogy, and subsequently Rowland's hybrid memory provide stronger additional support for EMH than either Donald or Rowlands' initial claim.

3.2.3 Integrationism and Scaffolding

Richard Menary refers to the second-wave arguments as being *cognitive-integration-style* ones in which internal and external processes are said to co-ordinate to complete cognitive tasks (2010, 234). Cognitive integration is complementarity-based and not reliant upon parity. Cognitive integration relies upon the embodiment of humans and the bodily manipulation of external vehicles (2010, 234). A feature of cognitive integration is that cognition is more than just mental acts or processes such as learning, recognizing, and remembering (2010, 230). Integrationists believe that the value of the organism manipulating and co-ordinating vehicles in the environment allows the organism to perform new or enhanced cognitive functions it otherwise couldn't, or to improve on those it could already do (2010, 231). Examples of integration are the use of a calculator to speed up math skills or to do functions you couldn't do, or using a notebook as extra memory storage and improving on the forgetful inner memory.

Embodiment is a precondition for manipulative abilities and our interactions via external manipulations are prerequisites for higher cognition (Menary, 2010, 232). Cognitive integration places the "dynamics of the system into a wider cultural and normative setting" (2010, 233). Menary's own theory of cognitive integration is grounded in the manipulation thesis put forth by Rowlands (1999) according to which cognitive processes are said to be, in part, made up of bodily and physical manipulation of exograms.

Menary points out that EMH arguments lead to understanding cognition as hybrid, involving internal and external processes (2010, 228). Integration arguments explain how internal and external processes coordinate together in cognitive task completion, and require an understanding of the manipulation thesis, which is the normativity of bodily manipulation of external vehicles of cognition. Cognitive integration is neither motivated by causal coupling to external resources, nor by the presupposition that the mind is in the head and then extended into the world. The primary motivation of cognitive integration is our embodiment, that is, the bodily manipulation of external vehicles of cognition (2010, 229). We are embodied and so we engage with the world in this way, primarily through sensorimotor engagements manipulating our environments. This manipulation consists of hybrid processes made up of inner neural processes and bodily ones on external vehicles, and our goal is to understand the nature of this integration (Menary, 2010, 229).

Integration theorists argue that cognition is not brain-bound. Philosophers and cognitive scientists describe cognition as a “clump of mental acts or processes that come under broad headings such as: remembering, perceiving, learning, and reasoning” and a problem arises due to the difficulty in identifying cognitive processes versus psychological processes (Menary, 2010, 229-230). Integrationist theory holds that it is wrong to suppose all cognitive processes and vehicles are in the brain (2010, 231). Menary draws upon empirical examples to argue that if all cognitive processes are done in the brain, then it would not make sense for us to engage in, for example, linguistics, or to do mathematics beyond mental arithmetic. Coordinated bodily processes and environment, such as linguistically engaging in knowledge exchanges, or using pen and paper to do math, enable us to do things we otherwise couldn’t do (2010, 231).

The manipulation thesis is not based on a parity principle, but describes the carrying out a cognitive practice of integration which is governed by its own norms. While parity is functional-based at the grossest level of functionalism, integration does not assume functional equivalency. As with complementarity, the vehicles as external resources are engaged because they are different (2010, 234-237). Cognitive integrationists provide a taxonomy of different kinds of integration.

Bodily manipulation involves cognitive practices, for instance doing math using pen and paper (2010, 237). Another type of manipulation is self-correcting actions such as using language to self-talk, speaking instructions to oneself as a corrective tool. Two remaining types are biological coupling, for instance sensorimotor contingencies, and epistemic manipulation, for example playing Tetris and imagining rotating the pieces at various angles prior to seating them in the video game (2010, 237).

Cognitive practices are norms that govern the manipulation of external representations in completing a cognitive task. Cognitive integration is normative because we acquire a practice which is an established method of manipulation to produce an end. Writing out, transforming and updating plans, and using maps for shared navigation, are examples of such methods (2010, 238). There are various types of norms. They can be purposive when the activity is engaged in for an end. Corrective norms are used to correct an activity in pursuing an end. Manipulative norms involve manipulating inscriptions of a representational system. Interpretive norms have a wider significance and are of interest to others. Manipulations of, for instance, mathematical notations, are normative and have a physical causal dimension (2010, 239). The embodying of norms in an activity is a cognitive practice of manipulating representations, for instance, writing, re-reading and re-rewriting as an active creative approach, is form of problem-solving in that it makes the writing more clear. It is difficult to compose an essay in your head (2010, 240).

Cognitive integration uses first-wave arguments to establish that cognition is hybrid. The manipulation thesis motivates cognitive integration and is understood in terms of cognitive norms (2010, 241). Unlike external cognition theories, the manipulation thesis does not have the parity principle as its starting point, and does not rely on a functionalism formulation that Menary argues is flawed from the start since it assumes the position it attempts to displace (2010, 234). That is, parity and functionalism arguments encourage a way of thinking about cognition in terms of a discrete cognitive agent who begins with the internal and extends into the world by way of arguing for the cognitive role of the environment based on functionalism (2010, 234). When viewed in terms of cognitive integration, Otto's notebook contains external vehicles which are integrated with internal ones and so are "constituents of the same cognitive process" (2010, 236). Otto manipulates external vehicles in his notebook to get the directions to the museum. The overall system that includes Otto and his notebook is integrated because of the co-ordination of the internal and external to complete the task.

Like Menary, Kim Sterelny (2010) claims that parity does not go far enough in recognizing that we engage with our environment through cognitive extension. Sterelny maintains that organism and environment are scaffolded to include language, niche construction and other historical environment adaptations, which have cross-generational effects (2010, 480). Arguing for a more general phenomenon of organism and environment scaffolding, Sterelny states that there is evidence of scaffolding in cultural practices, as with parents' ideas and actions transferring to the child. He emphasizes that there is more than just the mind and mental world extension; the whole body and its environment engage in extension as well. The scaffolding view proposes that in addition to depending on environmental resources, human cognitive capacities have been transformed by those same resources (2010, 472).

Sterelny argues that the single agent focus of, for instance, Otto and his notebook, is a mischaracterization of the human-tools relation, failing to recognize many of the advantages of scaffolding which go over and above the individualized portrayal and involve shared resources and a social setting (2003, 243). He views extended mind cases as special instances of a more general phenomenon that involves collective use of resources and language (2010, 480). Sterelny argues that although extended cognition theory is plausible with single-user resources, there is no need to privilege such a small space. While Otto's notebook is an external cognitive component, environmental resources can also be involved in mental world extension (2010, 480). This is because Sterelny sees the relation between humans and their tools as mutually supportive in that using epistemic artefacts, for instance deploying a notebook as a memory store, enables the portability of mental representations, which in turn explains our ability to use such artefacts (2003, 243). Engaging in collectivity in the social domain entails the constant coupling and decoupling of agent and environmental resources involved in scaffolding because these external tools are in the public domain and need to be individualized at each use (2003, 252). When engaged in resource sharing, scaffolded minds recognize that information resources, for instance maps and road signs, are in a shared space and are reliable because they are shared (2010, 476). I can take time to develop a relationship between agent and resource, however, on the positive side this relationship is stabilized once developed. Sterelny draws on Sutton's (2007) recounted example (based on Evelyn Tribble's work), in which Elizabethan actors in a play were able to rapidly memorize upwards of 70 parts in any given year. Sutton suggests that environmental support such as the structure and consistency of the scripts, other actors and physical layout of the theatres played a role in the actors' cognitive capacity. By contrast, Otto's notebook is an external cognitive component that has been individualized and so is stable in that sense, but lacks the collaboration and adaptability of environmental resources, which often includes other agents (2010, 477). Sterelny states that while it is true that agents adapt to their environments, they also adapt their environments to them. Examples of such adaptations are master-apprenticeship roles and the intergenerational flow of information in the form of social learning that is recorded and passed on from parent to child (2010, 471).

3.3 Complementarity Approaches: The case for group memory

A key objection to EMH that can be satisfied with the complementarity approach is the type of objection raised by Kourken Michaelian (2012) and Paul Loader (2013), who take issue with the objectification or container view of memory in which external memories, such as those said to be contained in Otto's notebook, are static, unified and unchanging. To bypass this concern Michaelian recommends emphasizing the nature of the overall system, while Loader proposes an enactive approach that focuses on the act of remembering. Both Michaelian and Loader suggest complementarity as a way around container and objectification challenges for external memory.

Michaelian (2012) argues that while external memory might be a potential problem for parity, a shift in focus to systems and complementarity could alleviate this concern. He makes it clear that he does not dispute Otto's notebook constituting a form of external memory, but he does question what exactly external memory means. While he does not dispute the strength of parity in terms of the functional aspects of external memory performing internal memory tasks, Michaelian claims that functional parity is not sufficient to establish mind extension (and therefore memory extension) (2012, 1156). He portrays the EM arguments as circular, beginning with the fact that if Otto's notebook is determined to be external memory, then by definition it is assumed to consist of mental states and dispositional beliefs, and this in turn would be sufficient to establish mind extension (since memory is part of the cognitive package so to speak) (2012, 1157). Michaelian challenges the "simple picture" of Otto's notebook as external memory as being false in terms of its appeal to the container view of memory in which memories are static unified unchanging events. Michaelian does not see the notebook as being at par with internal memory since it does not display sufficient internal memory-like features. That is, the notebook is a stable fixed container, whereas internal memory is "leaky container at best", subject to imperfections such as forgetting or limited detail recall (2012, 1157). For example, the information in Otto's notebook contains specific directions to the museum including street names, while Inga might recall just the number of blocks between turns forgetting a street name or two.

Another area in which external storage is unlike internal memory is in terms of the way memory is stored and retrieved. Michaelian claims that just because something is written down does not necessarily mean it has been endorsed. Furthermore, internal memories are subject to encoding, something that he claims is not possible with externally stored information. Finally, retrieval processes for internal memory are complex, involving reactivation and reconciliation, while externally stored information is directly accessible and read off the page (2012, 1156). Michaelian's closing suggestion is compatible with the complementarity principle in that he says that what is really at stake is the nature of the system and its operating principles, and how the system gets things right (2012, 1161). In other words, complementarity emphasizes the differences in the components that span from the brain and body to the environment, regardless of whether or not memory is portrayed as a container for beliefs.

Loader's enactive view supports complementarity but not parity due to the way in which memory is portrayed in parity arguments (2013, 167-176). Similar to Michaelian's concerns about memory, Loader claims that Otto's notebook is not extended because of "objectification", or the "storehouse" model of memory (2013, 167). For Loader, memory is not a store but a type of action (2013, 173). Loader claims that Clark and Chalmers have an objectified account of biological memory and that this view is also evident in their impressions of external memory (2013, 170). His challenge is that the parity principle is constructed in such a way as to objectify both internal and external memory. He claims that Clark and Chalmers' description of Inga's internal memory as "notebook-like" is not evidence of an internal store, but is a result of prior interaction with notebook-like artefacts (2013, 173). Regarding memory in general, Loader explains that first, "memory might not be a store at all" and second, "that remembering might be active in a *stronger* sense than a reconstructive account of memory by itself allows – i.e. that it might be fruitfully understood as a type of action" (2013, 173, italics his). According to the enactive view, Otto's manipulation of the notebook would be an *act of remembering,* and the contents would be neither externalized memory nor beliefs. What Loader is objecting to is the nature of external storage in general being viewed as any sort of memory or even at par with memory. Furthermore, Otto's case as presented by Clark and Chalmers (1998) presupposes that there is a process of storing and using external memory (Loader, 2013, 176).

Some advantages of the enactive view are that privileged access and location are not limiting factors as with the extended view (Loader, 2013, 173). Regarding privileged access, Loader explains that if remembering is a type of action rather than accessing a stored memory object, there is no reason to imagine others accessing it (2013, 173). Consequently the EMH past endorsement requirements actually go against the case for privileged access because the conditions themselves expose the external memory to the access of others should the conditions fail, and for instance, Otto's misplaced notebook becomes exposed to tampering (2013, 173).

Loader explains that the enactive view of internal memory is fairly indisputable in the case of procedural memory (such as riding a bicycle), which is not one fixed episode or representation, but spread across the neural circuitry. However, enactive memory is a tougher sell for other types of memory, and this part of his theory is a work in progress (2013, 174). Loader suggests that due to its storehouse portrayal of memory, the best that EMH ca do is to argue that based on complementarity some memories can be stored externally. He claims that the Otto/Inga thought experiment fails to provide good reasons for extended memory. Highlighting problems with the objectification of internal and external memory and issues with past endorsement, Loader proposes the enactive view as an alternative to EMH. According to Loader, the enactive view circumvents the problems of EMH because enactivism focuses on remembering as a type of action, not on access to contents of a store.

3.3.1 Transactive Memory

Complementarity can offer constructive explanation and appease objectification challenges by way of transactive memory, which Sutton et al. describe as an incidence of joint remembering with no need to consult external resources other than the other mind (2010, 19-33). The classic example of transactive memory in action is that of older long term married couples finishing each other's sentences, appearing to each recall pieces of common experiences, which together recreate an accurate depiction of their autobiographical experience such as a shared vacation. While Sutton et al. (2010) label transactive memory recall as an example of socially distributed remembering, what they are describing is a case of true extended mind and cognitive processing since the external mental states and mark of the cognitive demanded by EMH objectors *are* found in the minds of others. Since complementarity involves flexible and dynamic co-opting and coupling of different components to form extended cognitive systems, Sutton et al. (2010) draw upon it as an ideal supportive principle for transactive memory wherein other people can serve as external cognitive resources.

Amanda Barnier, John Sutton, Celia Harris and Robert Wilson (2007) approach memory sharing in terms of the framework for extended cognition. Their focus on people rather than artefacts as external resources moves them toward the social aspects of extended cognition. They highlight the benefit of studying understandings of relations between natural and/or cultural aspects of group cognition, which typically comes in the form of individual members or small groups. As in the example of the long term married couple, the emergent properties of transactive memory make it so that the sum of knowledge of the group is greater than the sum of the individuals. Although transactive memory systems are more likely to develop and most likely to be more efficient in closer knit groups (those with much frequent contact), it might be possible amongst casual acquaintances (Barnier et al., 2007, 38).

Daniel Wegner explains that transactive memory is concerned with understanding the manner in which groups process and structure information. The activity or mental operations between an individual and processes of the group are analyzed in order to predict individual and group behaviour (1986, 185). He argues that the group, consisting of a set of individuals, together forms a “group mind” as a form of transactive memory, in which individual group members act as a form of external memory for the rest of the group (1986, 185). Breaking down this process, Wegner analyzes transactive memory in terms of its components, which are individuals (1986, 186). He explains that individual memory has three stages: encoding, storage, and retrieval. Stored information is organized and stored as connective sets, for instance, “red” and “tomato” are each encoded, as is the connection between them, and this is how we learn (Wegner, 1986, 186). Wegner explains that with *internal* memory we are not conscious of the exact location of the information but we are able to contextualize and associate to find it. For instance, we can jog our memories to recall our often dialed friend’s phone number. For an individual, *external* memory, in terms of external storage, is fairly unproblematic when artefacts are viewed as aids (1986, 188). Individuals store information internally by *item* and *label*, whereas external encoding includes *location* and *label* (Wegner, 1986, 189). Successful encoding of either type (internal or external) of information requires a label to be encoded internally and at least one other piece of information. With transactive memory, other people can be locations for bits of knowledge. For instance, Wegner explains a simple case in which a student can be an external storage facility for her name, should the professor not learn it. What the professor has to know is the location (student’s memory) of the retrievable information with the label (student’s name) (1986, 189).

Wegner argues for a characteristic of transactive memory network, which is that a person is often able to answer questions beyond her internal storage, relying on the memory of the group. Transactive memory encoding is done by sorting out the pieces and where they will be stored within the group. Retrieval begins when one person requires information that she has not personally stored internally. A transactive memory system is a property of the group, not solely housed in one individual (Wegner, 1986, 190). The system unfolds as an almost automatic consequence of social perception in that we are co-operative and attentive to what other group members like, and what they can be expected to know in particular groups (Wegner, 1986, 190).

In a positive way, the impact of transactive memory on individuals is that they benefit from not potentially overlooking information since retrieval is done within the group. On the negative side, the added complexity of the group increases the potential for confusion and error, in the form of incomplete information paths, and knowledge and responsibility allocation within the group. As with any group project, the transactive mind is susceptible to freeloaders. The specific knowledge and performance levels of each member of the group can influence and affect the group's behaviour.

Applications of transactive memory exist in the form of interaction between a teacher and a student, who at first form a transactive memory system that is "lop-sided" in favour of the teacher's memory. The aim of this transactive memory interaction is to transfer the student's reliance on the teacher's internal memory via instruction to the student so that eventually the student can establish a more permanent memory system of her own which could include notes and her own internal memory (1986, 202-203). Transactive memory systems are evident in organizational management during restructuring when group members are shuffled and new integrations are formed (Wegner, 1986, 205). In an organizational setting such as a large department store, together the salesclerks have a uniformity of knowledge about their retail outlet, and each clerk holds specific knowledge about the products in their department. However, a group is at risk of overestimating its capabilities, members overly trusting and depending on other group members, or overconfidence of individual group members. Rotating the salesclerks between departments satisfies human resources headcount but sales could suffer due to the reduced expertise in specific product knowledge (1986, 205-206).

3.3.2 Distributed Memory

Distributed memory is a variation on transactive memory with emphasis on the environmental context of recall, in which each member of a particular group in a particular context contributes their piece of the overall operation. Edwin Hutchins' (1995) famous example of distributed cognition is his description of group operations on board a navy ship in which pieces of information about the ship's navigation are spread across the people, equipment and other media, all working together in a finely tuned seamlessly operating system. The stability of the environment and the members acting as a team, each knowing their piece of the information necessary to operate the ship, suggest to Hutchins that cognition is a natural extension of a group and artefacts in use by the group. Michaelian and Sutton explain that Clark and Chalmers' active externalism suggests remembering to be a cognitive process, with memory viewed as a standing cognitive state (2013, 1-2). In ordinary use, remembering can be hybrid across various external resources, most often with the external seen as memory traces or triggers with the actual "remembering" limited to neural processes in the brain and in this way external resources are seen as cues at best (2013, 6). An entailment of HEC is that remembering is distributed across various external resources, including technological and social types. Michaelian and Sutton attribute a convergence of Clark and Chalmers' active externalism and Hutchins' distributed cognition as the basis for research into this area in which, "Neural, bodily, physical, and social components of such complex coupled systems need not be alike: rather, their distinctive features and capacities complement each other in combination so as to realize the relevant processes collectively" (2013, 6). An example of a distributive memory context is that of actors in a play, each one having memorized the lines of their particular character. The actors' lines are cued and delivered based in sequence by cueing off the lines of the other actors. In this example no single actor knows all of the other actors' lines, yet collectively they know the whole play.

3.3.3 Collective Memory

Complementarity is evident in collective memory by way of interactions between distinct components in and across cognitive systems (Sutton, 2008, 43). Both the collective memory and the memories of the individuals that form the collective contribute to how the group both creates memories and remembers them. In his 1925 seminal paper, "The Collective Memory", Maurice Halbwachs offers an early 20th century reference to a societal collective memory that is more than just a cultural history of events. Halbwachs sees culture as imbedded in the memories of its members, each individual with her own perspective and participating in the collective whole. The individual is doing the actual "remembering" in collective memory, but the contents of mind consist of all of the elements that mark its relation to various collections (individuals can be part of more than one group, for instance an individual can identify with a group within a group). Under this view societal remembrances are possible even though individual consciousnesses or group members are at different life stages. Halbwachs argues that his idea of collective memory within a particular society or group is different than the group's history in that events are not clearly demarcated as they are in an historical recount of occurrences referenced in sequence using a timeline. Collective memory has continuity beyond the individual lives of its members. Halbwachs draws upon the view of the individual lifespan in terms of the collective, in that the individual consciousness experiences duration in terms of the group. The collective memory of a society is composed of the collective memory of composite groups, a social memory that transforms as does the group. For example, as older members die off and newer ones are born into the group, all at different life stages, the continuance of the collective memory is preserved within the life of the group. Since the group continually recounts and shares its memories although members come and go, there is a continuous narrative thread passed on within the group throughout the lives of its members. The effects of collective memory are more than just external triggers. The collective memory serves as a cultural reference. In Halbwachs’ view the individual is a piece of the collective whole, whose individual consciousness is described in terms of its intersection with the collective times. Halbwachs' message is that individual consciousness is not isolated, but is instead an overlapping stream with other individual and collective consciousnesses, with currents being defined as points of intersections of collective time.

3.3.3.1 A Model of Individual and Collective Memory

Thomas Anastasio, Kristen Ann Ehrenberger, Patrick Watson and Wenyi Zhang construct a model of the processes of memory consolidation depicting their theory that individual and collective memory formation are analogous processes that occur at different levels of memory (2012, 2). By “levels of memory”, they mean to acknowledge the way memory is studied at various magnifications or levels of abstraction. Anastasio et al. broadly describe memory as “the ability to form long-lasting constructs”, and this ability is attributed to both individuals and social groups (2012, 2). They use the term “entity” to describe any person or group that possesses the property of memory. While individual memory is studied in terms of neuronal, brain and psychological levels, social entities form collective memories at “supra-individual” levels such as couple, family, community, and nation and so on. The structure of the collective levels may be hierarchical (nation, family, couple) or horizontal since an individual can belong to many groups (culture, religion, nationality) (Anastasio et al., 2012, 8). Memory serves as part of the basis for enabling entities in decision making and taking action (2012, 2). An example of collective memory is group reminiscence at a family gathering. A recalled family memory is more than the sum of its parts since individuals recollect their own memories as well as trigger remembrances in other family members, remembrances might not have otherwise emerged in solitude (Anastasio et al., 2012, 56).

Anastasio et al. emphasize three aspects of memory, which are the processes of *consolidation*, *remembering* and the *structures* that enable memory processing and storage. The processes of consolidation and remembering together provide the basis for memory formation, and when these memory processes occur in the collective they are analogous to those of the individual. In both individual and group entities, memory consolidation involves the conversion of fleeting unstable bits of information into a "stable representation of facts and events, including a representation of the world and the entity's place in it" (2012, 2). Memory formation involves the process of transferring short term disruptable information to long term, stable, changeable but persistent stores (2012, 3). Memory formation loosely employs short term and long term memory stores, between which Anastasio et al. insert a component that selects items for long term storage. How the memory structures differ is that the individual structures consist of neurons and brain regions while the collective memory structures are exograms (Anastasio et al., 2012, 3).

The "three-in-one model of consolidation" depicts the core elements involved in creating and stabilizing memory in the individual, as well as where collective memories are created and stored (Anastasio et al., 2012, 72). Their model consists of three elements which are the *buffer*, the *selector/relater* and the *generalizer* (2010, 70). The buffer is modelled on short term memory and functions much the same way. As the information in the buffer is consolidated, it "teaches" by way of generalizations that are formed and stored into long term memory. How this happens is by way of the selector/relater which acts as an association-processing machine (2012, 69).

Anastasio et al. use the example of Google's search engine to partially explain the consolidation process. They explain how Google's algorithm discovers and makes connections by mining huge amounts of data, creating associations but not necessarily classifying or categorizing them. While the selector/relater does not attempt to relate *every* available item, it does select for association items to which the entity pays particular attention (2012, 70). The generalizer then extracts general themes based on the input data and stores these in long term memory. Activation of these simple processing components of buffer, selector/relater and generalizer constitute a single pass of the irreducible elements required for consolidation to take place in an individual entity. Learning occurs as a result of the two-way interactions between the buffer and selector/relator and the selector/relator and generalizer, in that the recursive looping nature of this dynamic process influences the formation of new memories (Anastasio et al., 2012, 71). For example, the buffer can temporarily hold an image of a dog and the selector/relator connects this image to other items by way of categorization in relation to other objects and animals. The generalizer learns to recognize the image of the dog along with meaningful and useful knowledge such as what acts dogs are capable of (2012, 69).

The model demonstrates how individual and social influences penetrate into the making of collective memory. The associations that make up the collective memory in individuals are a subset of meaningful encounters or influences in their particular environment. The model is situated within a context provided by the entity, which is the physical body and brain in the case of an individual, or the social group for the collective entity. For broader explanatory purposes, the model is framed to operate within the goals, plan, emotions and desires of the entity, for instance social group, religion or family (Anastasio et al., 2012, 72). The more their collective strata at the individual level overlap, the more "collectives" of memory the individuals share.

Groups of individuals who share social frameworks will engage in collective memories of those groups, for instance, religious, ethnic, family, organization affiliation (2012, 72-73). For example, recollection at a family picnic involves each member contributing facts that others may have forgotten, or triggers other memories that they might not have recalled alone (Anastasio et al., 2012, 56).

At the collective level the buffer deals with such things as media journals, archives and artifacts. The relater governs debate, agreement, dialogue and “contest and negotiation”, and the collective generalizer works with books, viewpoints, museums, belief systems and paradigms (Anastasio et al., 2012, 72). For example, Supreme Court justices who consult each other on the law regarding the case at hand, including legal texts and precedent cases, are applying “consolidated collective memory structures” such as law textbooks and court records for a more extensive collective remembering. In cases of collective remembering, the resulting recollection of the group can be greater than of each individual. Collective memory exists as a “synergistic, emergent phenomenon” rather than a common version the individual memories of the group members (Anastasio et al., 2012, 58). The model portrays the realization of collective memories in terms of static information in the buffer, social interactions in the selector/relater, and group or cultural memories that are more deeply incorporated within the generalizer. The model accounts for situational and close environmental influences at the first two levels, while the cultural roots are more deeply engrained as long term memory within the generalizer component (2012, 73).

3.4 Complementarity and Technology: The case for E-Memory

Robert Clowes claims that if, as HEC theorists propose, humans are “flexible, hybrid and unfinished creatures”, then the types of things we co-opt as cognitive resources will have an effect on the way our minds are shaped (2013, 107). Since we are in fact agents living in a digital world, and since memory is used as a test case for extended mind arguments, Clowes stresses the importance of exploring the question of whether Electronic Memory (E-Memory) is part of our mind or just a "significant environmental tool which changes some of the processing profile of our brain" (2013, 131). Our increasing reliance on E-Memory warrants analysis as to whether these technological resources should be counted as parts of our minds (2013, 107).

Clowes describes E-Memory as pervasive, and as having a novel incorporation profile, something that is reflected in the novel cognitive possibilities of human E-Memory couplings (2013, 107). By "novel" Clowes means that E-Memory resources "provide capacities which by support, extension or replacement have distinctive quantitative or qualitative properties" over and above those of internal or Organic Memory (O-Memory) (2013, 111). E-Memory is defined as "digital systems and services we use to record, store and access digital memory traces to augment, re-use or replace organismic systems of memory" (2013, 107). There are four dimensions that contribute to the novel properties of E-Memory, the first two of which Clowes maps onto conditions that are part of Clark and Chalmers' parity principle. Clowes matches the E-Memory dimensions of *Totality* and *Practical Cognitive Incorporability* to the *Constancy* and *Facility* requirements of the parity principle (2013, 122-123). The *constancy* and *totality* factors are comparable since the notebook resource is a fixture and constantly consulted, while the scale of computer technology has permitted larger "notebooks" capable of much more in-depth content (2013, 112). The *practical cognitive incorporability* and *facility* factors are reflected in the ease with which the external resources provide the information we seek. Both the notebook and E-Memory are considered to be at-the-ready for information look-up. Digital technologies that aim at "total capture" and "total recall" reflect the totality of E-Memory. The trend of *lifelogging* makes use of all available digital traces from all areas of user engagement such as Facebook and Google to build a personal history based on the capture of episodes or information in an individual's life (2013, 112-113). Clowes presents this type of E-Memory use as roughly analogous to the internal O-Memory equivalent of autobiographical and episodic memory. He also claims that there is an analogy between the O-Memory semantic subset of episodic memory and the information obtained through the use of fast and easy Google searches and Wikipedia looks-ups on a regular basis for information we may already have in O-Memory (2013, 113-114).

The final two criteria for parity, which are *trust* in that the agent automatically endorses the information, and *prior endorsement* in that the information has been previously consciously endorsed by the agent, are problematic for E-Memory (Clowes, 2013, 123-126). This is because the two remaining E-Memory factors of *autonomy* and *entanglement* raise paradoxical issues when it comes to trusting previously endorsed information. On the one hand, we are able to store and preserve original data, yet on the other hand the interfaces for accessing these data are constantly changing (2013, 116). We know the data are out there, but we may eventually have trouble accessing it. Clowes explains that part of the problem is that information is *processed* as trace data rather than merely *stored* in E-Memory repositories. For Clowes, traces are types of evidence we leave behind as a result of interacting with "devices and the informational cloud beyond" and can be in the form of "iconic representations" such as digital pictures or voice recordings (2013, 115). Other types of digital breadcrumbs result from engaging in web surfing, shopping, browsing blogging or social media. Digital memory traces are often understood in terms of group interaction rather than at the level of the individual. The trace data of people-people and people-organization interactions that are stored in massive online repositories is put to use by multiple users for purposes that go beyond what was originally intended (2013, 112, 115). The indexing and artificial-intelligence based retrieval systems that are constantly restructuring and reconstituting traces complement our cognitive profile, however they function "relatively independently" of us as human agents (2013, 112). That our digital information is regularly reordered electronically is often "cognitively opaque", or transparent to the user. For example, the order in which items appear in our search engine results is a factor of our prior searches and selections based on previous results. Although this is a trait that could be considered comparable to the way in which O-Memory works, the dynamic incorporation of new knowledge is not as readily evident with E-Memory in terms of "what we knew before and what we remember now" (2013, 116). That is, we do not continually store away new memories, the new information is incorporated into what we already know.

The fourth dimension of E-Memory is *entanglement*, which concerns the way in which data are stored, and is best understood in terms of relational tracking between people. For example, social media systems such as Facebook store memory traces of individuals' lives and present them in relation to the memory traces of others (2013, 116). Google and Wikipedia can be viewed as forms of "hyper entangled semantic memory" in that they rely upon voluntarily shared knowledge stores that are linked and cross-referenced in a vastly distributed way (2013, 116).

3.4.1 Cognitive Hybridity, Complementarity, HEC and HEMC

Clowes analyzes the impact of E-Memory on human cognitive capabilities in terms of how HEC and Complementarity versus HEMC theories deal with cognitive expansion and cognitive diminishment (2013, 131). With respect to cognitive expansion, he sees the novelty of E-Memory combined with the complementarity principle as accepting of potentially new cognitive hybrid systems that are composed of inner and outer resources. HEC and Complementarity jointly favour cognitive expansion, yet the novel profile of E-Memory raises concerns about the depth of its incorporation into cognitive profiles. This is because, for one, the *entanglement* dimension of E-Memory could be viewed as a form of memory tampering with the agent unable to determine the validity or context of the external memory. An example of this sort of problem is depicted in the fictional film *Memento* in which a man suffering from amnesia struggles to use external memory resources to "retain memory" and recover his identity, yet is unable to trust the degree with which the resource has been tampered (2013, 124). In the film, the protagonist struggles to piece together events using only photographs, notes and tattoos, without knowing the context and sequence of each. Due to the *autonomous* nature of E-Memory, there is a risk of such subtle changes to the memories that the agent may not even notice (2013, 124). An example is a photograph that has been photoshopped in that the background has been altered to either add or exclude particular elements. While slight modifications might not be problematic at first, the extent of the changes or losing sight of changes upon changes, could become problematic. For example, in information technology, a technique called "lossy" compression is used to reduce the amount of computer memory required to digitally store large amounts of data. Audio and video content such as files for MP3 players and YouTube are automatically compressed this way. Lossy compression results in lower resolution, which in most cases does not noticeably affect the overall picture or voice quality. For example, music stored on iPods is compressed in order to digitally store multiple song albums. Copies made directly from the digital master undergo one barely noticeable lossy compression. However, if lossy compressed files are in turn compressed due to saving and resaving the files, the quality suffers so that the gaps in the music become noticeable or critical words in online presentations become too fuzzy as to affect interpretability. Alternatively, “lossless” audio files do not undergo compression and offer the highest sound quality but take up large amounts of storage.

Clowes highlights what he calls the “paradox of credulity” wherein an agent will trust a particular cognitive system that he should actually distrust. Clowes explains, “the more credulous a given subject is, the more likely he is to trust systems he should not, and potentially treat those systems as part of his mind” (2013, 125). Agents need to trust that their minds are working properly, and this also applies to E-Memory. Elaborating on this idea of trusting our minds, Clowes states that we generally assume that our mind and its parts are operating in our best interest. We operate on the basis that a thought is our own and we do not disown a thought even if that thought is dissonant with our other thoughts or is self-destructive in any respect. That is, we do not normally attribute agency over any of our thoughts to others, since to do so is a sign of mental illness such as schizophrenia. It is doubtful that the same charitable outlook on cognitive dissonance will be adopted with respect to externally stored information (2013, 127). When we seek information from the web via one of our iDevices, we generally trust the reliability of that information. However, the subject’s lack of complete confidence in the reliability of a deeply incorporated system will prevent him from total mind immersion into electronic gadgets and web technologies. Clowes speculates that trust relations between an agent and E-Memory will serve to fundamentally limit the amount of incorporability (2013, 125).

Clowes indicates that regardless of causal profile or external resources, agents are better understood when seen as coupled with their technology than without it (2013, 131). He suggests that one approach going forward is to posit a spectrum between traditional minds at one extreme and those heavily reliant on E-Memory at the opposite extreme and to try to determine sensible bounds (2013, 131).

3.5 Conclusion

In this section I have demonstrated that while parity and functionalism form the basis for Extended Mind arguments, complementarity and Extended Mind together show that memory extension can be more easily accounted for than full blown extended cognition. This is evident from the various types of group or shared memory as well as specific forms of individual memory. Complementarity in the form of integration, scaffolding, and manipulation of external resources is used to demonstrate hybrid memory under those respective circumstances. As depicted in the following table, EM support ranges across a spectrum from parity based single user arguments to complementarity based multiple user arguments.

Table 1 — Extended Mind Support

Parity Principle	**Author**	**Feature**	**EM Significance**
External resource substitute for internal	A. Clark and D. Chalmers	Otto's notebook	Functional based substitution, past endorsement criteria
Complementarity Principle	J. Sutton	Exograms include artefacts, other minds	Internal and external resource coupling, different components playing different roles
Co-operative Complementarity			
Extended Functionalism	M. Wheeler	Generic memory	Functional equity for inner and outer, inner is not privileged
Manipulation of environment	M. Rowlands	Hybrid memory	Manipulation of external information bearing structures
Integration and Scaffolding	R. Menary	Single user focus	Improved or enhanced cognition by using external vehicles
Language, Niche construction	K. Sterelny	Group focus	Cultural practices and narratives, extension within a group
External Memory and Other Minds			
Transactive Memory	D. Wegner	Group memory	External resources consist of one or more individuals
Distributed Memory	E. Hutchins	Group memory	External resources are other people, each contributing their cued piece
Collective Memory	M. Halbwachs	Group memory	Societal memory dynamically formed by individual members
Complementarity and Technology			
E-Memory	R. Clowes	Technological hybridity	Use of technological resources, and their effect on human practices and memory

Although the complementarity principle is presented as a second wave basis of mind extension, there remains an unresolved tension as a result of the arguments for and against mind extension. We remind ourselves that what is at stake in this debate about cognition outside the head is not an accurate description of the outer behaviours of many Ottos and their notebooks, but a theory of cognition and mind extension that argues for what is going on undercover. That is, the picture on the outside for both theories is the same in that a person is using an external device to store information. The debate concerns the nature of cognitive processing involved in the human and external resource coupling, specifically the cognitive status of external elements, as shown in Table 2. Adams and Aizawa suggest there is a confusion about the difference between things that merely cause cognitive processes and things that are cognitive processes, the root of the problem being the uncertainty about what exactly cognitive processes are (2008, 101). Robert Rupert argues that HEC merely adds a complicated taxonomical layer in cognitive science research (2004, 2013). He maintains that HEC arguments for cognitive states or processes extend beyond the body, these arguments support only an interactively organism-bound cognitive system, which is HEMC (2004, 2013). Andy Clark replies that HEMC is unduly restrictive (2010b). Mark Sprevak argues that HEC's functionalist requirement is so coarse that it forms its own counterexample (2009, 1-10). Michael Wheeler claims that Sprevak's Martian Intuition example is not well formed (2010, 262-264).

Table 2— Cognitive Status of External Elements

Challenges to HEC	**Author**	**Feature**	**EM Significance**
Causal coupling, Process versus system	F. Adams and K. Aizawa	Cognitive processes	Claim that there cognitive processes are confined to the brain, other areas can at best qualify as vehicles of cognition
Functional concerns, natural kinds, past endorsement dilemma, internal memory characteristics	R. Rupert	HEMC	Claim that HEC offers no more explanatory value than HEMC so opt for simpler theory which is HEMC
Too coarse-grained functionalism	M. Sprevak	Martian Intuition	Claim that HEC's functionalist requirement is so coarse as to form its own counterexample

The next major section of this thesis presents the benefits of computational modelling of mind. Since memory has been used as a base trait in EM arguments, I will show in the following chapter the benefits of using computational modelling for EM purposes. In Chapter 5, I present my own model of human memory extension which conforms to a particularly rigourous type of computational model.

CHAPTER 4: THE BENEFITS OF COMPUTATIONAL MODELLING AND THE MECHANISTIC APPROACH

The purpose of this section of the thesis is to present the benefits of computational modelling of mind. Since memory has been used as a base trait in Extended Mind arguments, I will explain the benefits of using computational modelling for Extended Mind purposes in respect of memory. In Chapter 5 I present my own model of human memory extension which conforms to a particularly rigourous type of computational model.

Andy Clark maintains that to understand the cognizing that a person as a socially and technologically situated entity can do, requires the study of the class of systems that include cognitive loops through the body and the world, a view which he characterizes as HEC (2010b, 1059). Computational modelling is beneficial in demonstrating and resolving some key issues at stake in the arguments for mind extension by way of models that can be used to more offer in-depth explanations. This occurs by way of their depiction of the underlying processes involved in human and external artefact couplings, such as those couplings outlined in Table 1. Computational modelling also allows for a substantive depiction of the nature of the challenges outlined in Table 2, a depiction which can lead to some resolutions

There are at least two main reasons that EM theories stand to benefit from computational modelling. First, that EM arguments have in common is that they feature information being processed by the mind, and computational models are particularly suited for the demonstration of explicating the ways in which the mind processes information. Second, a model of the processes and mechanisms involved in memory creation and recall can serve to make evident the nature of the controversy between HEC and HEMC and highlight specific points at which the theories are at cross purposes.

This chapter begins with a discussion of the nature and advantages of modelling in general, after which the particular benefits of computational modelling are presented. Marcin Milkowski (2013) argues that computation, which is a base ingredient in most cognitive models, should be understood as information processing, and that cognition is possible only when computation is physically realized. He argues that because information processing is but one part of a mechanistic explanation, computation on its own cannot sufficiently describe cognition. This chapter demonstrates support for Milkowski's claims that the *mechanistic account*, which consists of algorithmic, constitutive and contextual specifications, is an explanatorily advantageous method over traditional computational modeling. This will be done by discussing these traditional models, including Herbert Simon and Allen Newell's (1971) classical view, D. Rumelhart, G. Hinton and J. McClelland's (1986) connectionist approach, Jerry Fodor's (1983) modularity of mind, David Marr's (1982) theory of visual perception, and Aaron Sloman's (1978) computational structure of an intelligent system, in terms of the mechanistic approach. Next, the advantages of using a mechanistic view for modelling extended human memory will be discussed. Finally, Robert Wilson's (1994, 2000) computationalism and wide memory argument will be presented in a mechanistic way further demonstrating the applicability of the approach.

4.1 Nature and Strength of Modelling

The basic toolkit of models is that there are entities and there are basic relations between entities. While models provide a classification of phenomena and lead to an emergence of understanding and exploration of implications, a particular model may not be the only possible explanation for the data, especially in the case of behavioural modelling (Stephan Lewandowsky and Simon Farrell, 2011, 26-28). As soon as there is interaction between entities you can explain behaviour either descriptively by observation, or explanatorily via causal relations, and these fall into three broad classes of cognitive models (Lewandowsky and Farrell, 2011, 25). The sole purpose of descriptive models is to provide a simple representation of a data set in terms of the model's parameters. These models do not have psychological content but do have psychological implications (Lewandowsky and Farrell, 2011, 26). The second and third classes of cognitive models strive to illuminate the workings of the mind rather than the data. Explanatory models describe all cognitive processes in detail, and everything within their scope is specified. This type of model is contrasted with the class of models that characterize cognitive processes but are neutral about the mechanics of that stage (Lewandowsky and Farrell, 2011, 26-28). Expectations from models include the classification of phenomena, emergence of understanding and exploration of implications (Lewandowsky and Farrell, 2011, 26-27). Consider an example of the descriptive model that depicts the results of students' exam marks plotted on a histogram. Each coordinate represents a mark for each student, and the plotted graph represents the distribution of the marks across a set of individuals studying the same course content. An understanding emerges due to the shape of the line graph. Whether or not the line forms a bell curve can provide insight into implications that can be explored, for instance, the nature of student learning, the marking scheme that was used or the level of difficulty of the course content.

Lewandowsky and Farrell explain that in general the modelling of ideas is beneficial in that data can never speak for themselves and verbal theories can be incoherent or ill-specified (2011, 10). For example, Venn diagrams are a useful way to model arguments. Diagrams of one or two sets can easily be carried in the head, but complexity increases with three or more circles resulting in more information than could be worked out strictly in the head. Pictorial representations assist students in picking out soundness, validity and consistency of arguments. It becomes increasingly difficult to have to remember the contents of three circles and to not include the contents another circle. For example, you are asked to solve a logic problem in which you are given the names of four players and clues as to which of three sports they play, and asked which player does not play both the first and third sports. The grid shown as Table 3 provides an at-a-glance answer to the puzzle, provided the clues were correctly documented on the grid.

Table 3 — Puzzle Solution Grid

Player	Tennis	Soccer	Badminton
1		X	X
2		X	
3	X	X	
4	X		X

Other characteristics of models are: that they are used to predict data, that they can depict several alternatives, that models can be compared against each other, and that an instantiation of a model means that all assumptions of a theory have been identified and tested (Lewandowsky and Farrell, 2011, 10). For example, a climate change model provides predictions based on historical data. Economic models feature variables that can be changed in order to explore limits to growth scenarios that are compared against each other. The Ptolemaic and Copernican systems both satisfied the same predictions and had problems making new predictions, but the 16th century Copernican model was adopted as the simpler explanation of the observable data. Almost 300 years later, as a simple mechanical demonstration of the earth's rotation, Foucault affixed high up in an observatory, a swinging pendulum that left a trail of sand on the floor below, demonstrating that the earth rotated one degree every four minutes. The Copernican model satisfied this prediction of earth rotation while the Ptolemaic model could not explain it.

4.2 Computational Modelling

4.2.1 Computation and Information Processing

Marcin Milkowski believes that while a computational account of the mind can constitute a genuine explanation if the mind is computational, “there is more to cognition than computation” (2013, 180). He explains that the notion of “computation” is subjected to confusing terminology, for instance, as an algorithm, program, digital and analog. Milkowski analyzes the term “computation”, concluding that computation and information processing are used interchangeably even though information processing is not always digital as in, for instance, the case of a thermometer which can be either analog or digital (Milkowski, 2013, 24, 26). Milkowski argues that due to the emphasis on information processing in explaining cognitive systems, the notion of computation as strictly symbol processing is irrelevant insofar as explanation is concerned (2013, 24). He advocates classifying “computational” to mean “information processing” in order to find a common ground between cognition and computational explanation (2013, 180).

Piccinini and Scarantino support the need for clarification of computational terminology. Their claim is that the ways in which “computation” and “information processing” are used in cognitive theories are problematic in terms of clarity of use and theoretical standards (2010, 237). They explain that historically computation in cognitive science came from mathematics as a functional, digital account. Computation can be in the form of discrete digital elements, or an analog continuous information flow (Piccinini and Scarantino, 2010, 239). Information processing is quite different from numerical computation in that information can be broken down into types such as, semantic (natural) or non-semantic (non-natural). “Information” came from engineering as in the content of what was transmitted (Piccinini and Scarantino, 2010, 239-41). Maintaining clear terminology to reflect that computation as information processing is the processing of natural information enables potential independent research contributions to cognitive theories, avoids cross-purpose “talks” and comparing and contrasting of non-equivalent theories (Piccinini and Scarantino, 2010, 240-5).

When “computational” is used to mean information processing, a computational model is valuable as an abstract or descriptive level of theory. Milkowski advocates taking the computational theory of mind literally, and while that this does not mean that the mind is a computer, what it does mean is that at least one aspect of the mind’s organization is best described in terms of information processing (2013, 25-6). A benefit of a computational model of mind is that, since cognition is possible only when the computational description is realized, models of cognition have to line up to the testing, investigation and methodologically strict requirements of computational modelling (Milkowski, 2013, 51-52). For example, while the input-processing-output model of information processing is satisfactory at one level of description, it might not be sufficient at a more detailed level. That is, if data are inputted, sorted, and results are generated, the details of the type of sort and the required processing power might not matter. In this case it is sufficient to describe the process as input-sort-output. However, if some level processing detail is a concern, then the description could be represented by input-“shuffle sort”-output. The sequences of computational mechanisms can be expanded upon with more steps in order to avoid opaque black boxes, so there is less room for variation among the modules, and this can be tested with empirical data (Milkowski, 2013, 95).

4.3 Modelling in a Mechanistic Way

Milkowski provides a mechanistic account of the implementation of information processing systems. He explains that computations are performed by mechanisms, which means that they are realized by the organization of the mechanism's parts, and that these parts need to be distinguished in relation to the environment (Milkowski, 2103, 51). He explains that while classical theories posit theoretical entities, the mechanistic account says what these entities are. According to the mechanistic account, an adequate computational model covers three levels of explanation (Milkowski, 2013, 55). The first level is the *constitutive* level, which is the lowest level. The structures that realize the computation are found here, for example, the internal electronic parts of a calculator that move in response to the calculations imposed by pushing the buttons on the outside of the calculator. The middle or *isolated* level consists of computational processes that contribute to cognitive processing and causal explanation. At this level larger parts of the mechanism are specified along with interactions, activities and operations. This is the layer where explainable processes are found (Milkowski, 2013, 55). For instance, an algorithm that outlines the steps in carrying out a computation would be found at this level. The third or highest level of explanation is the *contextual* level wherein the function the mechanism performs is seen in broader context and includes the mechanism and its environment. This is the level at which objects and interactions are "topped-out" or explained in non-computational terms. For example, the context of an imbedded computer could be how it controls a missile (Milkowski, 2013, 55).

Milkowski describes the use of mechanisms as being advantageous for three main reasons (2013, 52). First, mechanisms delineate boundaries by pointing to what is constitutively relevant for them. Second, mechanisms are used in the context of a mechanistic explanation, which is a type of causal explanation. Finally, mechanisms are realized by structures comprising multiple levels of organization, one of which is computational (Milkowski, 2013, 52). Milkowski emphasizes that computations, "cannot float freely without any realizing machinery" (2013, 52). The lowest level must be realized by its parts, bottoming out.

Mechanisms are multi-level systems and the behavioural capacity of the whole system can be distinguished from the behaviour of its parts (Milkowski, 2013, 55). Since the mechanistic approach involves multiple levels of organization, it distinguishes information processing at various levels within the mechanism, one of which is the computational level. The mechanistic view involves algorithms, computation giving causation, structures and processes, and further requires that everything must be described. Specifications and parts, operations and interactions form the mechanism schema. Mechanisms can be nested within the hierarchy. All of these characteristics are provided that the mechanism description bottoms out at the constitutive level (Milkowski, 2013, 121-124).

Philosophers from the time of the publication of Bertrand Russell's 1908 "*Mathematical Logic as Based on the Theory of Types*" have understood that paradoxes can be avoided by applying a schema of types. This involves building a hierarchy of types, then assigning an instance of an entity to a type. Objects of a given type are built exclusively from the objects of preceding types (those lower in the hierarchy), thus preventing loops from which paradoxes emerge. In application to descriptive models, type theory precludes construction of descriptive models with self-contradicting characteristics. While these characteristics may be reasonably avoidable in simple models, they may not be so readily discerned in more complex models, such as those with many layers of description. Thus, the application of a schema of types cohering to Russell's prescription is a strong advantage in precluding at least one source of modelling problems.

Marcin Milkowski's three layer schema of descriptions coheres to a schema of types. As a result, computational models following the Milkowski schema have the inherent property of avoiding contradictory descriptions or paradoxes of the kind Russell's theory of types warns about. This allows the three layer model to slide up and down levels of description as depicted in Figure 12, without encountering self-referential paradoxes. For example, since Otto's notebook is included at the constitutive level of his long-term memory, then this notebook is *part* of his long-term memory. A different notebook, not used by Otto, and so not found at his constitutive level, does not constitute part of his long-term memory function. A parallel example would be that of a library collection. The "collection" at the conceptual level, is constituted by all of the books of the library. A particular copy of a book in the collection is one of the books that constitutes the collection. A different copy of the same book, perhaps owned by the mayor of the town, is not part of the collection even though it is the "same" book. The mayor's copy would be found in the contextual layer, not the constitutive layer of the library collection.

Although processes are modelled and can be realized in different mechanisms, the general methodological principles of explanation, confirmation and testing make comparisons possible. The essential causal structure is tested by way of assessing whether the process can be realized the same way in different information processing media (Milkowski, 2013, 94-95). Milkowski describes a computational process as a qualitative process that "transforms a stream of input information to produce a stream of output information" (2013, 43). His account is a form of transparent computationalism that can accommodate any kind of computation provided the computation is specified in terms of relations between input and output information states (2013, 43). Under this view, digital Von Neumann machines (in which the data and the program are stored separately), analog computers (data are represented by voltages or gears), quantum computers (data are stored as quantum bits or particles) and perceptions are all computational. Computational functions are realized by the organization of the mechanism's parts, which need to be distinguished in relation to the environment (Milkowski, 2013, 51).

The complexity of an algorithm cannot be used to predict its run-time performance without knowing the hardware and context in which the program is to be run (Milkowski, 2013, 180-1). That is, although the steps of the process can be plotted and defined by an algorithm, it is the physical device and context that determine the performance. For example, it would take longer to calculate large mathematical equations using a calculator than it would using a computer, even though the process and computations were the same. It is for this reason, Milkowski explains, that resource limitations cannot be explained computationally, at the isolated level (2013, 180-1). For example, Milkowski stresses that Simon and Newell's theory is constrained empirically by the limitations of STM, not a resource limitation, since their cryptogram problem could be executed more efficiently on a computer.

William Bechtel's comments are compatible with Milkowski's view. Bechtel explains how a mechanistic explanation is reductionist in the sense that the parts and operations within a mechanism are situated at a lower level of organization than the mechanism itself (2011, 160). To explain the mechanism involves, "describing or depicting the component parts, operations, and their organization (diagrams are often far more useful than linguistic description for this purpose)" (Bechtel, 2011, 160). Bechtel claims that understanding the mechanism means that its operation can be simulated by using a model. Integrated systems models are built by combining learnings about other parts to produce the operations in question. Mechanisms are structurally decomposed into their parts and functionally decomposed into their operations. Once this decomposition is complete, the mechanisms are lined up with the operations they perform.

Applied to biological systems, mechanistic explanation includes the fact that boundaries between organism and environment are permeable. Furthermore, the operation of the system may depend on features of its environment, whether internal or external to the organism (Bechtel, 2011, 167). Bechtel explains, “The mind/brain, itself and the organism as a whole are open systems and dependent on the environment; hence, the quest to understand how a cognitive agent together with its various cognitive mechanisms is situated in its environment is also well motivated” (2011, 168).

4.3.1 Isolated and Constitutive Levels

Milkowski describes the isolated layer as the level at which computational processes that contribute to cognitive processes and causal explanations are found (2013, 55). The algorithm at the isolated level explains what is going on underneath the observed behaviour. Andy Clark and David Chalmers’ (1998) Extended Mind Hypothesis is an example of an isolated level explanation. Frederick Adams and Kenneth Aizawa’s (2008) and Robert Rupert’s (2004) challenges to extended mind arguments also happen at this level. It is here that the explanation and functional details of the system are found. For example, this is the layer where human memory formation and recall would be described. The isolated layer consists of computational processes that contribute to cognitive processes, causal explanations, and symbol processing (Milkowski, 2013, 55).

Milkowski’s checklist for computational processes requires that all of the following are satisfied:

1. The initial and final states of the process are causally linked
2. If there are stages in the processing, they correspond to the stages of the system’s activity
3. The system is relatively isolated
4. The system supports interventionist causation

5. The system is organized
6. The mechanism's constitutive levels are at the bottom
7. The trajectory of causal states corresponds to the computation model
8. The computation model is complete
(Milkowski, 2013, 81-83)

The isolated layer is non-autonomous (2013, 55). From a structural perspective, the mechanisms of a computational model must be bounded at the architectural level with selection mechanisms independently organized so that functional properties are evident (Milkowski, 2013, 81). For example, modeling human memory formation and recall means describing all of the mechanisms and functions that constitute the process of how memory is formed and recalled. For HEC theorists, this involves Otto's internal memory and his notebook. The isolated and constitutive levels are not independent in that the constitutive level must be foundationally relatable to brain mechanisms with the fine grained process states lining up with both brain and mechanism (Milkowski, 2013, 82). HEC theorists would line up Otto's short term memory with his notebook. From a processing perspective, any separate steps and processes are causally linked, interventions such as counterfactuals are supported and the system is complete in that it is minimally explicable at an abstract level, enabling rigourous use (Milkowski, 2013, 81-3). Demonstrating this in terms of the HEC and HEMC debate, HEC theorists describe Otto's notebook as a constituent piece of his memory formation and recall. HEMC theorists claim that there is no cognitive processing going on outside Otto's head. Since the process of memory formation and recall is not disputed, the source of disagreement between HEC and HEMC theorists is at the constitutive level. It is the functional substitution of external mechanisms in memory formation and memory recall that are questioned.

Under the mechanistic account, the computational mechanisms of a model are causal systems organized functionally, which satisfy single-mapping wherein the function of the computational mechanism corresponds to a cognitive component (Milkowski, 2013, 61). The advantage of having the algorithm and mechanisms on separate layers is that the algorithm can be implemented on different mechanisms. Since traditional single-mapping functionalism is just one of its layers or explanatory levels, Milkowski describes the mechanistic view as a "robust functionalism" (2013, 62). The mechanistic account demonstrates that no computational explanation is complete without implementation, which involves the algorithm being realized in that the functions are mapped onto mechanisms. Since the algorithm and mechanisms are on different levels, the algorithms can be mapped onto more than just one set of mechanisms. For example, Bechtel (2011) explains functionalism in terms of computer programs. He states that a program is a recipe for getting the job done and can be written in different programming languages, and can be run on different machines comprised of different hardware under the input-processing-output model. The abstract idea of a program is "a description of a fixed set of operations to be performed on whatever strings or symbols it is given as input" (Bechtel, 2011, 169). The program gets its purpose from the function that we assign to it and this function is not dependent on the hardware on which the program runs.

4.3.2 Contextual Level and Multiple Realizability

Milkowski describes a functional capacity as being multiply realized if and only if its occurrence is due to different realizing structures. Furthermore, the causal mode of the capacity must be sufficiently different so as for the structures to be different. He explains, "For multiple realizability, we need to change the causal structure of the constitutive level without changing the fine-grained specification at the isolated level" (2013, 67). For example, two separate mechanical calculators of the same make and model do not constitute an example of multiple realizability, whereas a mechanical calculator and a slide rule do constitute an example of multiple realizability. In the first example of the two calculators, the mechanisms are the same. In the second example, different kinds of mechanisms are in use at the constitutive level.

The roles of the components at any given moment depend on the operation of the mechanism because without knowing the current operation and the selection process that originated it, we cannot determine if a system is functional or not (Milkowski, 2013, 63-65). Milkowski explains, “The functional role of a component is one of its causal roles, such that it contributes to the behaviour of the mechanism” (2013, 62). At the isolated level of explanation the mechanisms are described in non-computational terms, which is the basis for Milkowski’s more robust functionalism, an example of which is performing an addition operation of two numbers. This operation can be realized at the constitutive level on different mechanisms. A first mechanism is an abacus wherein the quantity of beads on wires represent numbers. Manipulation of the beads mechanically produces the addition result. A second mechanism would be a mechanical calculator having gears and cogs wherein numbers are represented by the quantity of teeth on a cog, and an addition operation represented by the multiple turning of a cog. Yet a further example is an electronic calculator wherein bundles of electronic charge represent numerical quantities and the accumulation of these bundles represent the final sum being sought.

Under the mechanistic view, the sequence of calculations to be performed is represented by the abstract description at the isolated level. The implementation of these operations is peculiar to the nature of the mechanisms on which it is implemented. This example of the operation of addition as realized on multiple different mechanisms is an example of multiple realizability because at the isolated level, the operation does not care how the sum is arrived at. Robust functionality separates the operations at the isolated level cleanly from the constitutive level whereby they are carried out. At the isolated level there is meaning and at the constitutive level there are causal relations and effects.

Milkowski explains that “it is not representations of reality that explain why mechanisms have certain capacities, but reality itself” (2013, 122). The functionalism in the mechanistic view involves strong equivalence in that the explanation is complete only if what it is that performs the task is known. There can be functional decompositions to form hypotheses, but if a number of models have different internal subsystems, they are not equivalent in terms of causal dynamics. These functional decompositions that correspond to structural and casual organization are explanatorily relevant under the mechanistic view. Functionalism alone is a weaker form of a mechanistic view because functional explanation is enough to present a possible explanation of how the phenomenon works. That is, the task is explained if the system suffices to perform the task, which is a form of weak equivalence. Milkowski claims that it is not enough to flowchart the system to generally show how the task could be implemented, we need to know some degree of the specifics of how it is implemented (2013, 123).

Bechtel (2008) supports this notion that the components of theories are reducible to their mechanistic parts based on the behaviour of the system, encompassing the functionalist notion of multiple realizability. Bechtel explains, “To understand why the mechanism behaves as it does, we need to understand organization of the parts and the environment... [And] need to look sideways to the causal factors impinging on the mechanism” (2008, 262). Advocating a reductionist method across disciplines, including philosophical systems related to cognitive processing, Bechtel holds that all theories can be broken down into three main parts: components, bridge elements, and the final theory (2008, 261). This common base across disciplines provides for enhanced systems and component analysis.

4.3.2.1 Implementation

For a mechanistically adequate model of computation to be implemented would mean that "the input and output streams are causally linked and this link along with the specific structure of information processing, is completely specified" (Milkowski, 2013, 53). A description of a mechanistically adequate model involves abstract specification of computation that includes all variables causally relevant for processing, and a complete blueprint of the mechanism on all three levels of organization (Milkowski, 2013, 54). An example of an adequate implemented mechanistic computational model is a payroll process for a company. The *contextual* level is described by the human resources request for a payroll forecast and the computer program that was written to produce the required output. The *isolated* level consists of the lines of computer code and subroutines that are called by the computer program to make the calculations. For instance, a subroutine may be invoked given as input the hourly rate and hours worked and outputting the result of the amount earned. The *constitutive* level is the computer on which the program is run. At this lowest level of mechanisms, different computers can be substituted insofar as they are able to execute the program code. In other words, as an example of multiple realizability, the program can run on any computer that has a compatible language compiler and sufficient storage to execute or run it.

4.3.2.2 The Contextual Level: Mechanistic Externalism

The mechanistic account addresses boundaries since an adequate explanation of a mechanism under this view consists of the three levels of explanation, which necessarily take into account the mechanism in the environment (2013, 156). The contextual level provides the setting of the behaviour of interest. That is, the behaviour is embedded in a context and this provides a means of testing by physically realizing the operations. For example, in terms of HEC arguments, the mechanistic account can be used to show how Inga and Otto display computationally multiply realized behaviour. At the contextual level, both Otto and Inga have the same environment so it is not the determining factor. That is, both Otto and Inga are humans and so have the same internal brain mechanisms, and they are placed in the same physical context at a street corner in New York City. Inga is asked to go to MoMA and she does. If we place Otto at the same corner and ask him to go to MoMA, he will do it after consulting his notebook. The environment is not controlling things, but is used to describe behaviour. At the isolated level I use an algorithm to explain what is going on underneath in terms of how memory is recalled. At the constitutive level, the algorithm is implemented or realized in mechanisms. In Inga's case this realization takes places inside her head. For Otto, the description at the isolated layer is realized in mechanisms both in his head and in his notebook.

4.3.3 Criticism of Computational Modelling

Valerie Hardcastle explains the role of computational theories and functional analysis as an explanatory strategy tying together the diverse disciplines in cognitive science (1996, 63). She notes that although computational theories of mind began historically as human computer comparisons of mind as program and brain as hardware, theories became more nuanced about the status of mental or psychological states and their relation to cognitive processing. A drive to reduce mental terms to physical ones resulted from a focus on decomposing the mind into primitive components and attempting to redefine mental elements in non-intentional terms (Hardcastle, 1996, 73).

Hardcastle sees the organism's ecological environment as a key consideration and so neuroscience must not be seen as just an add-on, but as an important domain about the relational structure and activity of an organism in its environment (1996, 7). Hardcastle's recommended unified theory across disciplines utilizes computational functional analysis as a methodology and neuropsychology as a bridge science to model a systemic explanation of an organism active in its environment and the relation of cognitive processing to brain functionality. She highlights a difficulty of importing data or theories across domains and since classical theory reduction is not successful, she proposes “explanatory extension” as a way of explaining across fields in a multi-disciplinary approach (1996, 11).

With computational functional theories providing the methodological basis for a pragmatic approach to cognitive modeling, Hardcastle recommends interdisciplinary program development via “bridge sciences” as an important connection between psychology and neuroscience to explain cognitive processes (1996, 10). She prescribes neuropsychology as a theoretical framework for such a task since neuroscience and neural net modeling gave us the ability to model brains purely computational at a lower level of organization as well as emphasizing important differences between how the brain employs strategies and how computers problem solve (Hardcastle, 1996, 10). Hardcastle’s worry is that the initial focus on computational theories has left ingrained at the heart of cognitive science an emphasis on “what the systems *do*, versus what they are made *of*”, a distinction that is problematic because it obscures what is truly going on between function and structure (1996, 80, italics original).

4.3.3.1 Response

The mechanistic view can ease some of Hardcastle’s concerns in that the mechanistic view can accommodate mechanisms within mechanisms. For example, a mechanistic account of human memory would, as in the Otto and Inga case, describe memory formation and recall at the isolated level and then functionally map this onto mechanisms at the constitutive level. These functional mechanisms can be in turn mechanistically mapped so that the more we come to know about the inner workings of neurons, the more reductive our mechanism within mechanism views can be constructed. In other words, Hardcastle's worry is about cognitive science's emphasis on function over structure, and computational modelling in mechanistic terms can easily accommodate new information about the inner workings of mechanisms down to the neural level. At the constitutive level of a mechanistic account the algorithm is implemented and mechanisms are specified, there can be mechanisms within mechanisms, each modelled according to the three levels. An example of theoretical research that could potentially provide sufficient information for a mechanistic view of a neural net brain function is Aleksander and Morton's (2008) proposal of a computational model of mind in the form of a kernel architecture based information processing system. They theorize "information" as deconstructed units of consciousness that, when run as executable "packets", link the inner phenomenological states with outward behaviour, resulting in a computational account of consciousness (2008, 80).

4.4 Mechanistic view of Traditional Models

4.4.1 Traditional Models and Classical Computationalism

There are specific lessons to be learned about computational modelling. Marr's (1982) three levels of computational theory, and Sloman's (1978) computational structure of an intelligent system, provide the basis for a method of modelling the mind based on both the computational processes and the architecture of a computer system. Considering Simon and Newell's (1971) classical computation simulation, Rumelhart, Hinton and McClelland's (1986) connectionist model, and Fodor's (1983) modularity of mind, we can see the strengths and weaknesses of the various approaches. Milkowski's (2013) mechanistic account builds on the lessons learned with respect to prior computational models. His multi-level account includes a strategy for functionally grounding information processes in mechanisms, which is useful in comparing and evaluating models by way of the same set of criteria, and serves as a methodological approach for future models.

4.4.2 Marr's View

Marr's three levels of computational theory are computation, representation and algorithm, and implementation (1982, 26). These levels are based in Marr's claim that understanding complex information-processing processing systems requires further understanding of representation and process (1982, 21). Marr talks about representations as, symbols that are meaningful to humans, and that are elements of formal systems for making entities or types of information explicit. For example, Arabic, binary and Roman numeral systems each formally represent numbers by way of a set of rules. The Arabic system uses the integers 0 to 9, binary uses 0 and 1, and the Roman numeral system uses letters. Another example of a representation system is a musical score for a symphony (1982, 21). Different systems are better suited for different uses, for instance, arithmetic is much easier to do using base 10 Arabic representations rather than the earlier Roman numeral system (Marr, 1982, 22). Marr uses *process* in terms of meaning associated with information processing carried out by machines and understood at different levels of explanation (1982, 22). At the first level there are the separate arguments as to what is computed and why and is a general analysis of the task. The second level is defined by the constraints that the process must satisfy. This level describes how the representational inputs and outputs are transformed via the algorithm. The third level shows how the first two levels can be physically realized (1982, 23-25). Marr explains that the three levels are loosely coupled in that for instance, the choice of algorithm is influenced by the task and the hardware on which it will run.

Milkowski states that although Marr's model is a good methodological tool, the problem with this competence model is that is spelled out as a purely "functional analysis of the task" (2013, 101). Milkowski claims that computational explanations in the form of algorithms, for example, logical arguments and general laws, are insufficient for describing how things work in that they are not specified enough to be normatively adequate (2013, 102). He criticizes Marr's theory as depending on algorithms as law-like instead of as a description of how things work. Milkowski accuses Marr of extrapolating a single mechanism at the constitutive level across all levels of his explanation. For example, all three levels of Marr's theory apply to the same device, and competence is defined in terms of particular given physical constraints such as process speed and environment (2013, 114). Milkowski explains that although Marr's model is a good methodological tool, the problem with this competence model is that it is spelled out in a pure functional analysis of the task and does not allow for intervening states, just input and output (2013, 118). Another problem with law-like algorithm explanations is that they are insufficient in describing the regularities governing complex phenomena, which rely on complex entities and are best understood in terms of what those entities are composed (Milkowski, 2013, 104). Milkowski explains that realist multi-leveled modeling of mechanisms is of greater value than mere proof that there exists a similar algorithm for another machine (2013, 102).

Andy Clark describes a general weakness of Marr's approach as mismatching levels in terms of analysis and organization. He states, "to grasp the origins of mindfulness in the organization and activity of neural matter we need to understand how the system is organized at higher, more abstract levels, and we may need to associate aspects of that organization with the computation of cognitively relevant functions" (2001, p. 85). Clark notes that top level algorithms are informed by the mechanisms in which the functions will be realized. In the case of brain functionality, the actual details of neural organization must be taken into account (2001, 96).

Along the same lines, Milkowski maintains that all of Marr's levels are autonomous and are not descriptions of the same domain. Milkowski states, "Marr's levels are actually relatively autonomous levels of realization (Craver 2007, 218) rather than levels of composition. In other words, at all these levels, we speak about the same device, focusing on its different aspects, rather than about various entities at different levels that comprise the same device" (2013, 115). For example, for Marr the brain could be described in terms of true physical characteristics such as colour, mass or volume, all of which, relative to each other, are autonomous descriptive aspects of the brain. Milkowski's levels more resemble the nesting of Russian Matryoshka dolls.

Milkowski claims that the mechanistic account is an improvement over Marr's levels in the areas of *composition* and *competence* (2013, 125). Mechanisms are *of* something such as a task, competence or capacity. Milkowski distinguishes operations at the isolated level from their instantiation at the constitutive level allowing for multiple realizability and separating the operation at the isolated from other considerations. For example the heart can be viewed under different tasks, such as pumping blood or making thumping noises (2013, 125). The mechanistic approach shows structural and causally relevant decomposition and so does not share the deficiencies of Marr's levels. No level in the mechanistic account is solely dedicated to competence. Marr's levels, and competence models in general, predict facts in question and can be empirically tested and explained functionally, but this is an explanation of a task, not a mechanism. For example, a model of translation competence is an incomplete mechanistic explanation, also known as a mechanistic sketch, which has been confused with the explanation of a psychological capacity to perform the task (2013, 125). A completely and correctly described mechanism results from satisfying the mechanistic levels of explanation. This is because unlike Marr's theory, there is no single level of function or structure. The mechanistic account requires that higher-level capacities are decomposed into lower-level elements to explain causal interaction (2013, 115). A further improvement over Marr's theory is that mechanistic hierarchies can be nested, for instance, the constitutive level of one mechanism can be analyzed as the contextual level of another mechanism. This is particularly advantageous if the lowest level structures such as neurons are functional mechanisms in their own right (2013, 114-5).

Milkowski claims that there is a natural link between Marr's theory and the mechanistic account, specifically that the mechanistic account is a more "robust species" of algorithmic law-like theories (2013, 122). The mechanistic view provides additional criteria that guarantee a reliable connection between the explanans and the explanandum since the description of explanandum is implied in the mechanistic description which includes antecedent or start-up conditions. The difference between Marr's theory and Milkowski's approach is that the mechanistic explanation is a process, not just a logical argument (2013, 120).

4.4.3 Classical Theory and Connectionism

Modeling in cognitive science involves task analysis in the form of input-processing-output, which is compatible with computational explanation, otherwise the explanatory target would not be known (Milkowski, 2013, 108). The classical computational and connectionist models are partial models since they are missing the hardware realization, or the mechanistic *constitutive* level. Minds as programs (Simon and Newell, 1972) and connectionist models (Rumelhart, Hinton and McClelland, 1986) are examples of theories that satisfy two levels of mechanistic modeling and so are unsatisfactory as computational models of the mind. Since one of the main functions of computer modelling is theoretical unification of cognitive phenomenon or of theories, theoretical unification requires, at minimum, a general framework. The more completely facts can be explained, the better. A purely computational account is not complete without either implementation or interaction with its environment. However, lack of mechanistic explanation does not mean there is no explanatory value (Milkowski, 2013, 131-133).

Herbert Simon and Allen Newell's (1971) classical computation simulation account of mind as program and brain as computer depicts the performance of a single agent within an information processing system. Simon and Newell explain that their strategy was to demonstrate human problem-solving capability by modeling a set of processes for storing and manipulating patterns to perform complex tasks that emulate human thinking (1971, 147). Their classical approach to problem solving involves a well-defined problem posed in such a way that subjects have a clear understanding of expectations. The problem is self-contained in that neither special training, nor knowledge outside that of what is provided, is needed to solve it.

How their model works is that structure of the human brain provides the structure of the task environment and the task environment determines the possible "programs" that can be used for problem solving (Simon and Newell, 1971, 149). The task environment delineates the core task, and the environmental constraints are grounded in known research at that time. Their theory assumes the seven item limit capacity of Short Term Memory (STM) as proposed by George Miller's (1956) research. Simon and Newell's problem-solving exercise shows how the system processes one item at a time. The system's inputs and outputs are held in a small and limited capacity STM. Long Term Memory (LTM) is "essentially infinite" but requires a longer access time to store symbols (1971, 149). This is demonstrated by their famous cryptarithmetic problem of asking subjects to figure out a problem of addition by substituting numbers for letters given "DONALD + GERALD = ROBERT", where D=5. This puzzle shows how human information processing and problem solving make efficient use of the available resources, continually evaluating progress for each step. To offset the limits of STM, their system offers a progressively deepening strategy that is evident in the way in which human problem solving is carried out. Simon and Newell found a regularity in how the subjects solved the problem. The results of the test showed the sequential processing steps that the mind follows when given this particular problem. The computational method used by Simon and Newell involves manipulation of a limited capacity short term memory store in order to solve a specific problem. When operating in the same physical environment with the same objective, the model demonstrates how the agent's expertise and intellectual ability are factors.

The classical computation simulation theories, as in Simon and Newell's test, concentrate on a serial process modeling the mind on symbolic processing. Milkowski points out that the classical computation simulation model involves a detailed level of encoding but it is incomplete in that it does not specify the mechanisms that correspond to the neural systems on which they are said to operate (2013, 8-25). His concern with classical cognitive models is that they lack grounding in functional mapping to mechanisms of mind (Milkowski, 2013, 25). Claiming that "there is more to cognition than computation", Milkowski states that what is required for a computational explanation to be complete, is "an understanding of how a computational system is embodied physically and embedded in its environment" (2013, 180). He explains that while the reaction time in classical models is explained computationally, the complexity of the algorithm cannot divulge or predict its runtime performance without knowing what hardware it runs on (Milkowski, 2013, 181). For example, Simon and Newell presuppose the environment as being a single purpose information processing system, which makes the system implementation and interaction with the environment outside the scope of their computational explanation

(Milkowski, 2013, 180). In other words, although the steps of the process are somewhat standardized, the time taken to perform the processes varies from agent to agent based on their particular reasoning and information processing capability.

Another example of traditional computational modelling in cognitive science is D. Rumelhart, G. Hinton and J. McClelland's (1986) connectionist model, which uses a general Parallel Distributed Processing (PDP) framework as a model for the connectionist view of mind. The PDP model depicts neural activity, which involves more detailed description than that of Simon and Newell's model. The PDP model demonstrates input-output streams as exemplars of a general rule. Data are inputted and information is held in an array of connections between the units of mental processes that are distributed across a neural network. PDP neural frameworks are designed such that the input and output are known, and the accuracy of the information contained in the connective associations increases as the network learns. The strategy for Rumelhart, Hinton and McClelland's particular model is to reflect learning in humans by the stages of the process of training the network on the past tense usage of English verbs. The model can determine the nature of past tense verb formation as either regular, in which a letter d is added to the end of the word, such as smile and smiled, or irregular, such as go and went. As with general PDP models, Rumelhart, Hinton and McClelland's model uses processing units, patterns of connectivity between units, rules for propagating patterns throughout the network, a learning rule, and an environment in which the system must operate (1986, 46). The model operates such that the input, English verbs, sets in motion patterns of connectivity which are reflected in the output of the verb in the past tense. In the case of an irregular English verb as input, the process involves a learning rule, for instance, the past tense of "go" is "went", and this rule is propagated across the network during the training phase. In this way, the system is able to participate in “associative learning”, combining the states of units for best fit based on the states and weights of surrounding nodes. The system can be on its own or part of a larger system environment (Rumelhart, Hinton and McClelland, 1986, 48-50). The PDP model is the most widely recognized form of connectionism, and involves input, neural network processing and output.

The connectionist model satisfies both the isolated and contextual levels but lacks lower level detail at the constitutive level. The problem in mechanistic terms is that their model does not describe mechanisms and so is an inadequate computational model (Milkowski, 2013, 22). The connectionist models focus on the level of neural structures, theorizing on a specific form of learning such as the PDP framework of generating the past tense of a given list of English verbs. This model is task specific in that the input is in the form of a list and the output is the result of the mind operating on that list.

4.4.4 Modularity Theory

Jerry Fodor (1983) sees his modularity system as advantageous over connectionism since his model operates at the level of symbolic code and demonstrates systematic thinking, which he deems necessary for thought. Classical models are criticized for outlining the mind as being unsystematic, which means that words are taken as input and each word is processed independently of syntax or semantics, and so the words are treated as a list and not a generated set (Fodor and Pylyshyn, 1988, 20; Clark, 2001, 161). Fodor adds that by making a “General Problem Solver” out of psychological elements modeled on computer components, “what does *not* follow is that there is some way of constructing such systems from the information given in *experience”* (1983, 35, italics his).

Fodor (1983) depicts the mind as modular, which is based in a functional view of psychological systems by analogy to computers. His functional taxonomy of cognitive mechanisms combines the calculating-machine approach in which symbol-manipulating devices simulate logical computer algorithms, with the mind as part of an organism interacting in the world (Fodor, 1983, 40). Fodor's theory includes intermediary subsidiary representational systems that present the "world" to the central processor. His "trichotomy" involves a computer, transducer and input system. The modules of the mind are domain-specific in that they are designed to deal with or process certain types of input. The function of the input systems is to get information to the central processing unit (CPU) and mediate between transducer outputs, which are then given to the CPU (Fodor, 1983, 42). So the output from the input system goes to the transducer, whose mediated output is in turn fed to the CPU.

The way Fodor's model works is that the transducer transforms environmental signals into cognizable input, which is passed on to particular input systems, whose output is then processed by the computer part or the central processor. There are at least six input systems, five of which correspond to the input for the five senses, and the sixth is for language. The input systems are modular and domain-specific, each with their own transducer, as well as input and output. The input systems are recognition functions that are information encapsulated in that the information processing within the systems is not affected by other information, for instance, a sight system is not affected by sound recognition. Input systems are mandatory, and operate quickly. Input systems produce basic, shallow output that is passed on to the central processor or computer (Fodor, 1983, 42).

Milkowski states that traditionally, cognitive science research posited computation to explain and predict a range of cognitive phenomenon, and the scope of the computational explanations varied with the strategy of the model (Milkowski, 2013, 5). Advocating a mechanistic account, he argues that computational models are explanatorily effective under the following conditions: their explanandum phenomena (usually involves the processing of information) is clear, analyzed and well understood; the explanation is predictive; algorithms are well specified; the explanatory components are specified in terms of empirically adequate mechanisms; and the model is implemented (2013, 133-134).

Under the mechanistic view, cognition is possible when processing is physically realized, not just described, therefore no purely computational account will be a complete account. What is needed is to account for the implementation of the model is to describe how the mechanism is embedded in the environment (Milkowski, 2013, 26). Milkowski criticizes Fodor’s account for not being implemented, since Fodor does not specify the brain mechanisms that relate directly to his modules (2013, 105). Fodor’s modularity theory falls under what Milkowski refers to as a “mechanistic sketch”, which means that the specifications and parts, operations and interactions of the modules are not completely described (2013, 123-4). The encapsulated information in Fodor’s model is not open to explicit description since these encapsulated modules are contained units that receive, process and output information. For Milkowski, a description is not complete if it contains units or opaque black boxes in which the processing input-processing-output chain is not fully explained.

4.4.5 Architecture

Purely computational models depict what Milkowski (2013, 61) refers to as single-mapped functional accounts in which the mechanisms of computer architecture are identified directly with cognitive processes, which is just one layer of the mechanistic model. An example of such a model is that of Aaron Sloman (1978) who takes a conceptual, functional stance regarding the structural components for an intelligent system that includes structures and processes that not only mirror a large scale working mainframe computer, but that also allow for such structures and processes to be located either internally or externally in the environment.

Sloman argues that in order to make progress in the area of philosophical modelling and computational approaches, research ought to focus at the conceptual level (1978, 9). He describes the foundation for his model of mind as an intelligent system as, “Going from grasping some general concept defined in terms of a structure, or a function, or some combination of structure and function, to grasping systematic principles for subdividing that concept into different categories” (1978, 10). Sloman lists the structural components necessary for an intelligent system: a *knowledge store* (a store of resources as well as a catalogue of resources), a *motivational store*, a *process-purpose index*, and various *temporary information processing structures* (1978, 93). He sees the intelligent system as interacting with its environment in such a way as to constantly generate temporary internal and external processes as it seeks to incorporate and appropriately apply new knowledge. For Sloman, the environment includes both the inner environment, such as the agent’s disposition as to cultural and social beliefs, and the outer environment, such as physical location and activity. He states, “The structures and processes may be either inside the mechanism or in the environment" (Sloman, 1978, 93). As to the model in action, Sloman explains, “it will be seen to be useful to blur the distinction between the mind of the mechanism and the environment” (1978, 93). The factual *knowledge store* includes language and procedural memory as well as a catalogue search ability so as to be able to efficiently discern whether or not the required information is in your internal memory. An index or catalogue of the contents of this store not only ensures efficient access but also gives a sense of what information may or may not be available without having to resort to exhaustive searches. For instance, it should not take very long for me to decide whether I know the current temperature in another city across the globe, or what number bus to take to get from Liverpool to Chester. Theorizing about possible ways in which the information might be organized, Sloman states, "The index may be implicit in the organisation of the store itself, like the bibliographies in books in a library, and unlike a library catalogue which is kept separate from the books. If books contained bibliographies which referred directly to locations in the library (e.g. using some internationally agreed system for shelf-numbers) the analogy would be even stronger" (Sloman, 1978, 96).

The *motivational store* which houses a resource store and catalogue governs those things implicitly involved in decision-making, such as the agent's preferences, goals, hopes and fears. The resources store is an ability and aptitude based container of the agent's abilities and aptitudes to be drawn upon for decision-making, for instance, linguistic capabilities and strategic planning. The resource catalogue is an organized store of abilities, indexed and structured for the most efficient access and update (1978, 98). The *process-purpose index* is where the reasons for actions are stored. A set of *temporary processes* is set up according to current needs, in the external sense much like a piece of paper used as interim storage while working out a mathematical problem. The internal initialization of temporary parallel processes allows for changing variables and monitoring of "sub-goals", current and next instructions, and output destination. Sloman indicates that this complex goal-directed information processing system demonstrates that there are different types of memory with different time-scales and functions (1978, 100).

These intelligent system processes in action require some form of *system management* and for this purpose Sloman adds three core processes, which are *central administration*, *monitoring*, and *retrospective analysis*. Much like a computer, the *central administrator* surveys and monitors available resources, calling to them to use for applicable tasks. However, sometimes the task or resources are deemed unnecessary or not worth the effort. Sloman explains, “Sometimes no selection can be made until a change has been made in the set of purposes for instance by inventing a compromise between two conflicting purposes. In at least some cases, the selection must be automatic to avoid an infinite regress of decision making” (1978, 101).

In cases where the system engages and then finds the task to be overwhelming or unmanageable, the central administrator will adjust its goal and resort to, other more complex methods if available, a change of plans, or simply abandoning the task altogether. Similarly, there are cases in which once the motives have been selected for action, the system automatically invokes action-generating procedures. These automatically activated procedures can happen when “a current purpose closely matches a catalogued specification of a typical use of an available procedure” (Sloman, 1978, 101). Sloman notes that automatic procedure invocation is necessary since, if everything required prior planning or deliberation, nothing could ever get started. In some automatic activation occurrences, monitors could be employed to reduce inherent risks (1978, 101).

Monitors are one of two types, either general or special purpose. *General purpose monitors* gauge and assess the physical body’s environment and are used for judging space, location and circumstances (safe or dangerous). These general purpose monitors are inner processes that scope out familiarity of encounters and the potential for infinite regress and wasted effort in the form of unnecessary repetitious procedures, such as remembering a geographic location, and not having to recreate the image or memory each time it is visited. A skill example is that of recalling mathematical skills used to solve equations, while quickly being able to assess the difficulty of the problem and recognize when to quit when for instance, sharing one dollar equally between three people. *Special purpose monitors* are increasingly complex, and transient by nature, for example, “Watching out for multiplication or division by zero when simplifying equations illustrates this: zero may be heavily disguised in an expression like: $a^2 + (a + b)(b - a) - b^2$” (Sloman, 1978, 104).

Finally, *retrospective analysis programs* are engaged to rethink and reassess past experiences for new learnings. Analysis of *general purpose* monitoring could involve wondering if one could have acted differently, taken a different approach to a problem, if the problem should have been filed away for future assessment or if a *special purpose* monitor should have been invoked (Sloman, 1978, 106).

Sloman provides a conceptual analysis of the necessary structural components for an intelligent system interacting with its environment, but his model is not adequate by mechanistic standards (see Milkowski, 2013, 61-65) Since descriptions of the mechanisms are incomplete, the model is not implementable. Like HEC, Sloman does not distinguish the “mind of the mechanism and the environment”, thus leaving unspecified as to when and how external resources are engaged. Under the mechanistic account, Sloman’s model lacks in clarity at the isolated level, and without complete explanations, his theory cannot be properly implemented. For example, his model lacks a clear decision process for engaging external resources. Another issue with Sloman’s model is that it missed factoring in memory research in other disciplines such as that of cognitive psychologists Fergus Craik and Robert Lockhart (1972), who criticize the multistore view in favour of a levels of processing approach. One of the main advantages of the levels of processing framework is its by-product of memory traces and the explanatory capability in accounting for deeper learning correlated with time and depth of processing.

Craik and Lockhart (1972) assess both the multistore and levels of processing memory models, seeing the major difference between the two types of framework being the importance of the nature of processing, rather than STM just holding information for LTM. A benefit of the levels of processing framework is its ability to demonstrate how deeper, more elaborate processing leads to deeper learning (1972, 672). Craik and Lockhart critique multistore memory frameworks, finding them unsatisfactory in terms of "capacity, coding and forgetting characteristics" (1972, 674). Regarding capacity, they explain that multistore approaches are unclear about what exactly they mean by capacity. That is, these models are based on the computer information processing analogy, and they often confuse capacity with storage limits of computer memory and the processing performance rate. Furthermore, in cases where both interpretations are present, the relationship between the two notions of capacity is not clear" (Craik and Lockhart, 1972, 673). Craik and Lockhart's stance is that processing capacity is a fundamental limitation, and storage capacity is to be understood as a direct consequence of processing limits (1972, 674).

Craik and Lockhart are in favour of the levels of processing approach as a conceptual framework for memory research, since it associates deeper processing with deeper learning and an improvement in memory. They conclude that multistore approaches are often taken too literally, while the levels of processing model provides a framework that is well positioned for research into the organization of information and its retrieval from the system. They explain, "This conception of a series or hierarchy of processing stages is often referred to as 'depth of processing' where greater 'depth' implies a greater degree of semantic or cognitive analysis." (Craik and Lockhart, 1972, 675). The depth of processing is directly related to both the agent's implied usefulness of the material and the tractability of the material to deeper processing.

"Thus, if the subject's task is merely to reproduce a few words seconds after hearing them, he need not hold them at a level deeper than phonemic analysis. If the words form a meaningful sentence, however, they are compatible with deeper learned structures and larger units may be dealt with" (Craik and Lockhart, 1972, 679).

4.5 Advantages of the Mechanistic Account

The advantages of the mechanistic approach to computational modelling are evident in the completeness of description of the mechanisms, robust functionalism and three levels of explanation. The mechanistic account does not allow for black boxes because computational mechanisms must be completely described. It is not sufficient to explain a process in the form of input-processing-output. The nature of the processing must be fully described. Incomplete functional models are referred to as mechanistic sketches due to the fact that they contain gaps in the specification of the mechanisms with respect to either its internal parts, operations or its interactions with other mechanisms. During the modelling process, mechanistic schemas can be used as temporary placeholders for gaps in processes, to be filled in with more details as they become known.

A mechanistic view has three levels. At the top is the contextual level which displays the explanandum phenomenon, the capacity to be explained. The isolated level in the middle contains parts of the whole system but not the system itself. At the bottom is the constitutive level where the composition of parts happens and only entities that are part of the mechanism itself are found. Figure 6 depicts these levels and their relationship.

The boundaries of the mechanism establish what an explanation of a phenomenon should include. There is no danger as to whether the mechanistic explanation is internalist or externalist because, as Milkowski explains, “if contextual effects prove important, they will be analysed as parts of larger mechanisms and thereby included at the isolated level of those larger mechanisms; if not they won’t” (2013, 124). In other words, the contextual level of the mechanistic account includes the environment of the mechanism and so will the explanation of the mechanism (Milkowski, 2013, 164). The role of the representational vehicle and content will be included at the isolated level. Furthermore, the success of the system depends on the way the world is, which is described at the contextual level, and content as processed information cannot be completely decoupled from environmental factors (Milkowski, 2013, 165).

4.5.1 Mechanistic View and Memory

With respect to memory modelling in particular, it is not just that “anything goes”, and memory should not be accounted for as a single phenomenon. Since memory involves several capacities such as Short Term, Long Term, and Working Memory, these should be explained separately (Milkowski, 2013, 125). The benefits of mechanistic accounts of modelling are that conjectures about organization of mechanisms are empirically tested, mechanisms are modelled causally, and causal interventions can be used to test whether the causal structure is correctly described (2013, 126). In cognitive science, mechanistic explanation is neither bottom-up nor top-down. Milkowski explains, “Top-down constraints are used to describe the explanandum phenomenon but this is not set in stone” (2013, 126). For example, neurological deficits might suggest that a set of capacities will break down under certain circumstances. As such, neurological evidence is important for computational modelling of human cognitive capacities (Milkowski, 2013, 126). Since memory is used as the base cognitive trait for testing hypotheses, using a mechanistic account in memory modelling would prove advantageous for cognitive modelling in general. An example of a computational approach to memory is Robert Wilson's (1994, 2000) wide computationalism and wide memory.

Robert Wilson's (1994, 2000) arguments for wide computationalism and wide memory were developed in parallel to first and second wave extended mind approaches. Wilson rejects the individualist account of computationalism while maintaining the standard notion of computation. His theory of wide computationalism involves computation as an extended process in the form of computational states and processes that can be instantiated beyond the individual.

Wilson claims that computationalism on its own is an insufficient explanation of how the mind works (1994, 352-359, 2000, 40-43). He notes that traditionally computation that governed cognition was portrayed as being confined to the skull, so computationalism was seen as individualist. However, Wilson sees no reason to confine psychological states within the constraints of individualism since "we are creatures embedded in informationally rich and complex environments" (1994, 355). He argues that while the computational view is useful for the individualist seeking systematic, scientific and psychological explanations in cognitive science, in general, human problem-solving essentially involves the "exploitation of representations in one's environment" (1994, 356).

Wilson maintains that a purely individualist computational theory of mind is insufficient in that it does not respect processes beyond the individual, leaving a gap between those processes and the individual (1994, 352). There are some cognitive contexts in which extended computation should not be controversial, for instance, when multiplying two numbers. If all of the calculations were done in the head, then the multiplication is internal symbol manipulation. Using pen and paper to, for instance, multiply two 3-digit numbers involves internal symbol manipulation plus active manipulation on paper, and so multiplication in this case is a causal process between internal and external symbols. The in-the-head computations are part of a corresponding computational system, which extends beyond the head. We store pointers to external symbols when doing complex mathematics, since, for example, the complexity of proofs of theorems necessitates the use of some form of external placeholder such as pen and paper, a blackboard or perhaps a calculator (1994, 356). Wilson explains that this gap between computationalism and individualism allows for the possibility of wide computationalism (1994, 357). Wilson notes that if at least parts of computation are extended, then those parts of or aspects to cognition will also be extended. So, he rejects the individualist notion of computationalism while using a standard notion of computation (1994, 352-356).

Wilson proposes *wide computationalist systems* that involve states and processes that are not fully instantiated in any individual. He claims that the computational systems that make up the mind can extend into environment and include the environment as parts of themselves. If computation itself can be an extended process, then in the same sense, so can cognition. A feature of this view is that computationalism of mind can be supported without having to endorse individualism (1994, 352-5). Wilson does not deny individual computationalism, but his wide computationalism denies that formal computational systems must be bounded in an individual, computationalism can be withdrawn as a support for individualism without rejecting computationalism itself (1994, 355). Wilson explains that the formal properties of mental states are often thought of as intrinsic properties of mental symbols, such as shape and size, however this notion of formality is misleading when applied to computational theories (1994, 357). Computational theories use what Wilson labels the *systemic conception of formality*, which is applied at the system level and “in this sense, the intrinsic, physical properties of symbols in a formal system are arbitrary” (1994, 358). This notion of formality is what provides the strength of wide computationalism, that it is “non-committal regarding the precise computational character of cognition” (1994, 359). Wilson explains that wide computationalism is in some respects analogous to wide functionalism, but provides a stronger case against individualism (1994, 355). That is, wide computationalism allows that individualism is true for some mental processes, but rejects all-encompassing individualism. This is because in Wilson’s wide computationalism the boundaries of the cognitive system do not have to be identical to the bounds of the individual.

Based on Wilson’s analysis, memory can be purely internal, bodily enactive or world-involving (2000, 40-43). The first and most narrow type involves traditional forms of procedural, long term and short memory which is realized within the architectural and non-architectural features of the brain. The bodily, enactive type of memory is realized within cerebral and bodily configuration encompassing an extension of procedural memory, for example, muscle memory in athletes. The third and widest type of memory involves internal and external symbols as extensions of other forms of memory to include external symbol systems. Wilson’s example of doing multiplication by processing using both the mind and calculator is an example of a world-involving cognitive capacity (2000, 40-43).

Wilson draws upon debates over the “storehouse” model and alternatives to it to show how memory is wide beyond the traditional view. He explains that the relationship that memory bears to past experiences and states of affairs yields an individuation of memory that involves its intentionality and this relies on a wide taxonomy (2000, 41). If the storehouse model is viewed as memory as correspondence to some state of affairs, then this view can serve as a basis for taxonomical width. Being prompted to remember by things in the environment, such as a string on one’s finger serving as a reminder to do something, is an example of locationally wide procedural memory. External systems such as the procedural enactments of remembering something and the strings as reminders, can effect “change in the cognitive capacities of individuals who interact with them” (2000, 41). Wilson cites research wherein bonobo chimpanzees develop symbolic capacities in symbol-rich environments, for instance, the organism and the symbol keyboard forms a cognitive system and memory and other cognitive capacities beyond itself (2000, 42).

Wilson draws upon the enactive view in which remembering is seen as doing, “enactively engaging with the world” (2000, 41). He explains that if memory is a ‘bodily enactive skill’ then enacting that skill to, for instance, tell a joke to ‘impress and entertain’ an audience is an application of a wide individuation of the memory making it also taxonomically wide (Wilson, 200, 41). To support his externalist notion of wide memory, Wilson demonstrates how the locus of control for memory can be located externally (2000, 40-420). While acts of communication involve internal representations in the speaker, “public and shared representations” occur each time we speak or write, since an external symbol pool is created and shared with others and it is clear that these “are not the province of any one mind” (2000, 42). Likewise, external storage memories such as diaries that store individual memories can be accessed by others, and can live beyond the author (Wilson, 2000, 42).

Under a mechanistic account, Wilson’s wide computationalism and wide memory arguments are compatible with abstract description at the isolated level. The strengths of Wilson’s account are that he explains some processes in terms of wide computation and his account essentially involves the processing of information. The weaknesses of Wilson’s wide memory explanation are that his system is incomplete since it is not specified on multiple levels, and it is not an adequate description across the constitutive and isolated levels.

4.6 Summary

In this section I have demonstrated that Milkowski's mechanistic view is an enhancement over traditional classical computational models in that its structure elucidates the benefits of computational modeling and demonstrates how the environment factors into cognitive systems.

Milkowski argues for computation as information processing. He maintains that computational modelling involves implementation, but not just mapping of physical to computational states (2013, 26). Computation involves information processing and the result of the implementation of a computational account is a mechanistic view (2013, 26-7).

The next chapter offers a Computational Model of Memory (CMM) that is compatible with the mechanistic view. The model is described in terms of the three levels of mechanistic explanation, and depicts the mind as processing information and embedded in its environment.

CHAPTER 5 COMPUTATIONAL MODEL OF MEMORY

The purpose of this section is to examine the arguments for and against Extended Mind by way of a computational model of memory. The Computational Model of Memory (CMM) is a philosophical model of memory that conforms to the mechanistic account and that can be applied to illustrate how the boundary issue is a challenge that crosses logical levels.

As we saw in Chapter 4, Marcin Milkowski (2013) offers a mechanistic account that offers advantages over traditional computational models. Using "computation" as "information processing", Milkowski defines a computational process as a qualitative process that "transforms a stream of input information to produce a stream of output information" (2013, 43). At the isolated (or conceptual) level, in which philosophical explanations are found, computational processes contribute to cognitive processes (Milkowski, 2013, 55).

Under the mechanistic account, computational functions are realized in the organization of and by the operation of a mechanism's parts, which need to be distinguished in relation to the environment (Milkowski, 2013, 51). The success of a mechanistic system in the larger world depends on the way the world is, which is described at the contextual level (2013, 165).

A major advantage of a mechanistic account is that functions and mechanisms are on different explanatory levels, and so a function can be mapped onto more than one set of mechanisms. The robust functionalism of a mechanistic model entails that the operational roles of the components are given by the operation of the mechanism (Milkowski, 2013, 63-65).

In order for a mechanistic account to be complete, there must be no gaps in the specifications of mechanisms. All internal parts, operations thereof and interactions with other mechanisms are explicitly described. A complete account comprises three levels of explanation.

The functional capacity to be explained is contained by the contextual level. The *contextual level* includes the environment and the boundaries which together establish a frame for what an explanation of a phenomenon should include. The *isolated level* (or conceptual level) contains parts of the system but not the whole system. Descriptions at the isolated level are of the parts of the mechanism along with their interactions. The *constitutive level* is where the composition of the operational parts happens. Only entities that are part of the operating mechanism itself are found at the constitutive level.

With respect to memory modelling in particular, it is not just that "anything goes", and therefore memory should not be accounted for as a single phenomenon. Since memory involves several capacities such as Short Term, Long Term, and Working Memory, these should be explained separately (Milkowski, 2013, 125).

This chapter introduces the Computational Model of Memory (CMM), a proposed schema of how the mind processes information to form, catalog, incorporate, store and retrieve memories. The model will be explained in terms of Marcin Milkowski's (2013) mechanistic approach. The model satisfies the bulk of Milkowski's mechanistic description of an adequate computational model in that the CMM's mechanisms are functionally mapped to brain processes, the model is predictive, implemented, and embedded in its environment. The CMM satisfies the philosophical constituents of his checklist.

The CMM's mechanisms will be fully explained and functionally mapped to brain processes, highlighting compatibility with memory research in other disciplines including psychology, neuroscience and cognitive science. It will also be shown how the CMM is useful in demonstrating the functional and substantive implications of over-reliance on either internal or external memory. At the contextual level of explanation, the CMM depicts memory extension and this will be supported by the Extended Mind Hypothesis and complementarity positions on memory.

The CMM will be diagramed within the three levels of Milkowski's mechanistic account and further, will be evaluated point by point against Milkowski's checklist for computational processes.

The implications for HEC and HEMC debates will be discussed in terms of the mechanistic approach. Challenges to externalism relating to past endorsement, parity, and system versus process will be elucidated using the CMM. Support for second wave Extended Mind Hypothesis arguments such as scaffolding, extended functionalism and complementarity will be demonstrated using the CMM.

5.1 The CMM as a computational mechanism: isolated and constitutive levels

Milkowski describes computational mechanisms used in modelling the mind as having "at least three levels of organization", and claims theoretical unification as one of the main functions of computational modelling (2013, 55, 132). The CMM aligns with Milkowski's categorization of computational mechanisms in that the CMM is mutually supportive of constitutive, isolated and contextual levels. At the isolated level, the CMM's mechanisms and their interactions are depicted as a system. At the constitutive level of explanation, the CMM's mechanisms are described in non-computational terms as per Milkowski (2013).

A mechanistic account of the CMM is advantageous in that describing the model with respect to the three layers shows how the model satisfies not only the computational processing requirements, but that the model aligns with known multi-disciplinary research. In order to be implemented, the described mechanisms must be realized. This section describes the isolated and constitutive layers of the CMM.

5.1.1 Elements of the CMM

The elements of the model at the isolated level are: the *Converter/Interpreter,* the *Buffer Pool*, the *Cross Reference* module, and the *Long Term Memory* functional blocks. Figure 1 depicts these elements and shows a block representing *External Storage*.

The four internal mechanisms function as inter-cooperating pairs. Each of the mechanisms will be elaborated upon in turn.

Converter/Interpreter	**Buffer Pool**
Scans for obvious logical errors and inconsistencies and salience. Screening process/function, reaches for more features, if not immediately obvious, on encountered information.	Limited Capacity dynamically sized store operating much like a cache in that once it is full, the newest version of information overlays the oldest.

Cross Reference	**Long Term Memory**
Searches associations based on recency of references. Multiple searches yield deeper associations. Catalogues the information to be retained in Long Term Memory.	Depth of search increases with multiple passes. Sequential-like search, newest to oldest, involving time and compare functionality.

External Storage
Information is stored externally, directly accessible for search and retrieval at any stage in the process flow.

Figure 1 – Computational Model of Memory

Figure 1 depicts the two sets of paired mechanisms along with the EXTERNAL STORAGE*. Later figures depict the model in operation in differing contexts.*

5.1.1.1 Converter/Interpreter (C/I)

The function of the first mechanism in the model, the C/I, can be described as scanning encountered information for relevance and importance. The highlight of the CMM's compatibility with developments in computational theories of mind rests in the presence of the

Converter/Interpreter mechanism. This particular mechanism and its location in the chain of information processing allows for an initial screening of input for logical consistency.

Moving from the isolated to constitutive level, a possible candidate for this C/I mechanism would be the insula brain region, which in humans acts as a screening mechanism to determine relevance of potential input. Vinod Menon and Lucina Uddin's proposed framework of how the insula operates suggests that the insula is "sensitive to salient events, and that its core function is to mark such events for additional processing and initiate appropriate control signals" (2010, 655). They postulate a "salience network" that is formed that includes the insula and cortex, whose function it is to "segregate the most relevant among internal and extrapersonal stimuli in order to guide behavior" (2010, 655). Menon and Uddin's model proposes that the core function of the insula is to identify stimuli and initiate control signals to appropriate brain areas that mediate attentional, working memory and higher order cognitive processes (2010, 658). The insula forms the core of the salience network acting as a filter that detects environmental stimuli, and "triggers a cascade of cognitive control signals that have a major impact on how such as stimulus is subsequently processed" (Menon and Uddin, 2010, 660).

5.1.1.2 The Buffer Pool

The function of the Buffer Pool is to house a pool of recent salient information that has been passed to it by the C/I. It holds this information for the C/I. At the constitutive level, the operations of the Buffer Pool are described by the research findings of George Miller (1956) with respect to STM and Alan Baddeley (1986, 2000 and 2011, with Graham Hitch, 1974) with respect to Episodic Buffer and Working Memory (WM).

George Miller’s research determined that STM has a bounded size of 7 chunks, with perfect recall occurring only 50% of the time (Miller, 1956). Chunks are defined as “familiar units of input”, which means information in a similar category, for instance, digits, letters or words. STM is where the brain stores information for quick recall. Miller also tested with increasingly large chunks but found that despite the agent’s familiarity with the information, the longer the individual words, the smaller amount of chunks in the STM capacity. This is due to the effect on what Miller calls “memory span” wherein the amount of time to recall, or state the actual words, is taken into account in the STM capacity. Longer words take longer to say and this affects the overall STM capacity, hence the “magical number” of 7, give or take 2 chunks. STM storage is temporary, and fleeting in mere seconds when the subject is distracted (John Brown 1958, and Lloyd Peterson and Margaret Peterson 1959).

Closely related to and sometimes analogous with STM is Working Memory (WM) which consists of the processes that temporarily store information. The standard definition of WM is, “the temporary storage of information that is being processed in any range of cognitive tasks” (Alan Baddeley, 1986, 34). In his account of the origins and development of the multi-component approach to WM modelling, Baddeley distinguishes between the “theoretical framework, which has remained relatively stable, and the attempts to build more specific models within this framework” (2011, 2). Baddeley explains that “working memory” evolved from the earlier concept of STM, noting that in some cases, they are still used interchangeably. He defines STM as referring to “the simple temporary storage of information”, while WM “implies a combination of storage and manipulation” (Baddeley, 2011, 4). A major development thought about in WM is Alan Baddeley and Graham Hitch’s (1974) Episodic Buffer as working memory. Further development of the Episodic Buffer (Baddeley, 1986, 2000) provides a link between

WM and LTM (the next functional block in the CMM's isolated layer), managing and grouping information across space and time. Baddeley saw the need for a conceptual framework depicting how input is processed and stored, and recommended that future frameworks be accessible to other disciplines. The Episodic Buffer is a temporary storage system that is capable of integrating information from a variety of sources (Baddeley, 1986, 2000).

The Episodic Buffer is so named because it resembles episodic memory, that which groups information across space and time. It can be described in terms of capacity, temporality, and components. In terms of capacity, the Episodic Buffer is a limited capacity temporary storage system integrating information from various sources. Its capacity is limited because of computational demand for simultaneous access of its components. In terms of components, the Episodic Buffer is a component or sub-system of STM, controlled by a central executive component that retrieves, manipulates and modifies information from the Episodic Buffer (Baddeley, 1986, 2000).

5.1.1.3 The Long Term Memory (LTM) Module

The function of LTM is to house a pool of historically encountered information. It is distinguished from STM in that LTM is unbounded in scope and features slower retrieval than STM. The LTM at the isolated level is constituted by the brain's Long Term Memory.

5.1.1.4 The Cross-Reference (XREF) Module

The XREF module is situated between the Buffer Pool and LTM, acting as a filter that manages Long Term Memory storage and retrieval processing. At the constitutive level, the operations of the XREF element are described by the research findings of K. A. Ericsson and W.

Kintsch (1995) with Long Term Working Memory (LT-WM) and K. Nader and O. Hardt (2009) with respect to consolidation and relearning.

Ericsson and Kintsch's contribution of Long Term Working Memory (LT-WM) includes "cue-based retrieval" into LTM that reflects the capacity of individuals to "attain reliable and rapid storage and access to information" (1995, 220). LT-WM efficiency is evident in the form of an acquired skill by individuals bypassing capacity limitations of STM for their specific skillset domains of expertise. For example, expert chess players have been shown to have an enhanced ability to imagine reorganized patterns of the pieces on a chess board. Subjects display a high degree of focus ability, coping with interruptions and successfully resuming activities. For example, players engaging in blindfold chess wherein the players are literally blindfolded and make moves by using chessboard notation. Some players can engage in multiple simultaneous games of blindfold chess, keeping track of the boards and pieces in memory (Ericsson and Kintsch, 1995, 237-8).

Ericsson and Kintsch's LT-WM provides a functional bridge between the short and long term memory components, and contributes explanatory measures for subjects with specific expertise. They explain, "The primary bottleneck for retrieval from LTM is the scarcity of retrieval cues that are related by association to the desired item, stored in LTM. Another problem with storage of information in LTM is that subsequent storage of similar information may interfere with the retrieval of the originally stored information" (Ericsson and Kintsch, 1995, 212). These constraints on memory performance are what prompted Ericsson and Kintsch to propose that a section of LTM, under certain circumstances, can be used to supplement WM. The resulting LT-WM module addresses the "association bottleneck", and accounts for the increased speed of retrieval from LTM. "Our proposal for LT-WM simply argues that subjects can acquire domain-specific memory skills that allow them to acquire LT-WM and thus extend their working memory for a particular activity" (Ericsson and Kintsch, 1995, 213). Empirical testing on subjects within skilled domain sets confirms Eriksson and Kintsch's hypothesis that information needed to complete a task has to be readily available, implying speed and accuracy of access to the information. Given the limited capacity of STM (G. Miller, 1956), and the slow retrieval of LTM (A. Newell and H. Simon, 1972), it would seem likely for there to be a possible interim LT-WM, between STM and LTM. LT-WM exemplifies the potential of increased efficiency in memory recall and retrieval with practice, as well as honing prediction abilities. They note, "in skilled activities and when subjects have had extensive experience with the task demands and acquired stable procedures for completing the task, they can foresee retrieval demands and develop memory skills to index relevant information with retrieval structures" (Ericsson and Kintsch, 1995, 239).

K. Nader and O. Hardt (2009) investigate the relationship between consolidation and reconsolidation of memory, concluding that consolidation resembles "re-learning". They define consolidation as "the time dependent stabilization process that leads eventually to the permanent storage of newly acquired memory" (Nader and Hardt, 2009, 224). What they found was that re-activation of a consolidated memory induces the same process as does consolidation, in that the memory state during the reactivation process shares many properties with the state that follows initial learning, making it a "relearning" (Nader and Hardt, 2009, 232). Reactivation is associative, involving a consolidated-like process. The recursive processing feature of the CMM during subsequent deeper recall attempts reflects Nader and Hardt's (2009) findings of the relearning process involved in reactivating a consolidated memory, one stored in LTM.

The following figures depict the CMM in operation, performing the memory functions of simple *Recall from Short Term Memory*, and *Recall from Long Term Memory*.

5.1.1.5 Simple Recall from Short Term Memory

The two interoperating pairs, which the C/I and the Buffer Pool, and the XREF and LTM elements respectively, make up the CMM at the isolated level. Putting the components together, it is possible to depict the model in operation performing a recall from Short Term Memory as a process flow diagram.

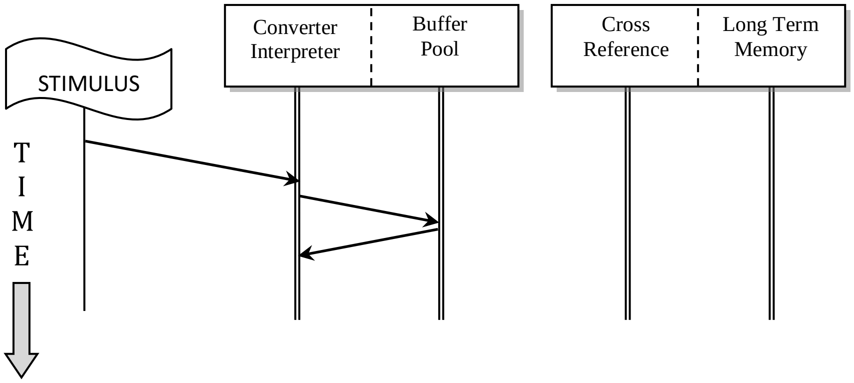


Figure 2 – Simple Recall from Short Term Memory

STIMULUS is recognized and made sense of at the CONVERTER/INTERPRETER. Requisite information is sought in the BUFFER POOL and found. The CONVERTER/INTERPRETER can then proceed to take appropriate action based upon that memory.

5.1.1.6 Recall from Long Term Memory

Again, putting the components together, Figure 3 demonstrates a recall from Long Term Memory. The CMM makes use of computational architecture and mechanisms such as the Converter/Interpreter and Cross Reference in order for it to build upon previously stored information. The CMM allows for learning in that with the Converter/Interpreter up front, it can train itself to recognize previously encountered information. Using the internal and external storage framework, the model allows for the incorporation of encountered information into the catalogued pool. The CMM takes into account the mind, memory, and computer architecture, along with parallel processing, networks, associative elements, swapping, cataloguing, cross referencing and data storage facilities (D. Rumelhart, G. Hinton and J. McClelland 1986; M. Minsky 1997; G. Piccinini 2010; G. Piccinini and A. Scarantino 2010).

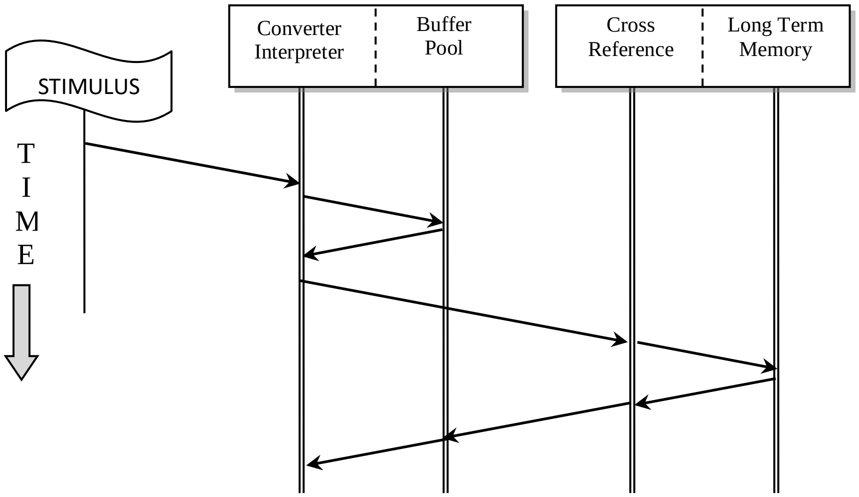


Figure 3 – Recall via Cross Reference and Long Term Memory

STIMULUS is recognized and made sense of at CONVERTER/INTERPRETER. Requisite information is sought in BUFFER POOL and not found. CONVERTER/INTERPRETER then proceeds to access CROSS REFERENCE module for memories catalogued in LONG TERM MEMORY. Having found a relevant memory, the CONVERTER/INTERPRETER can then proceed to take action based upon that memory.

When the mind encounters a stimulus, which can be in the form of external information or internal thought, the data is treated as input, then scanned, cross referenced and stored, in much the same way as a computer processes information. For example, if you were asked about your whereabouts prior to reading this page, the Converter/Interpreter would screen the question for salience, then find the answer in the Buffer Pool. An illogical or incoherent question such as "where were you tomorrow three days ago?" would not pass the consistency check of the Converter/Interpreter and then would be discarded (Figure 2). If you were asked where you were a week ago today at this time, you might be able to answer by cross-referencing the schedule of familiar events or associations such as a weekly departmental meeting, from long term memory (Figure 3). An example of an internal trigger is thinking about an upcoming vacation, searching STM for at-hand details, then LTM for memories of a previous trip to that location and the experiences you had, as well as any details about things you would change to make the next trip more enjoyable.

5.2 Contextual Level and Externalism

This section explains that part of the environment in which the CMM is embedded. Once the CMM enters a relationship in the environment, the mind can treat external memory under certain conditions as existing at the isolated level. External memory goes through those processes as depicted by the model. Internal and external information are interchangeable at the isolated level provided certain conditions are met. If the memory were to be altered, the C/I and XREF would reject the information as an actual memory. As with internal memory, the mind can jog its memory or can definitely say it does not recall this particular memory. Illusions cannot be distinguished from real memories in this frame. There might be a gray area in that it needs some further internal reference in order to be able to make a determination.

5.2.1 External Memory

The CMM provides for integration of resources internal and external in nature. External memory can be in the form of such mechanisms as paper notebooks, electronic notebooks, access portals to information on the Internet, or other minds. Figure 4 provides an illustration of the CMM in operation performing a recall from external memory.

5.2.1.1 Recall from External Memory

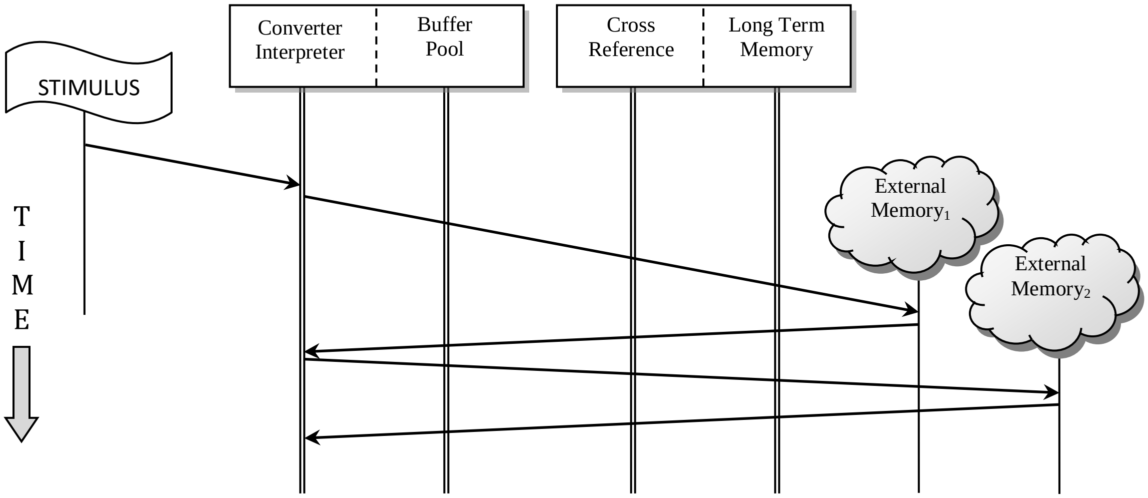


Figure 4 – Recall via External Memory

STIMULUS is recognized and scanned for salience at the CONVERTER/INTERPRETER. Requisite information is sought in EXTERNAL MEMORY$_1$ and not found. The CONVERTER/INTERPRETER then proceeds to seek requisite information in EXTERNAL MEMORY$_2$. Having found a relevant memory, the CONVERTER/INTERPRETER can then proceed to take appropriate action.

An example of a recall via LTM would be to attempt to recall your whereabouts a week ago. Not having weekly event associations to cue off, you could resort to your electronic (or paper) calendar, “external memory” for further cues or an instant answer, such as having coffee with a friend. Alternatively you could think more deeply for associations of timetables or events to jog your memory. You are free to consult external memory at any time, bypassing the deeper processing work of exercising the internal associations, cross-referencing and long term memory. A call to external memory can go straight from the Converter/Interpreter consistency check to external memory. Functionally, an immediate external call saves steps; instead of trying to recall specific events of a week earlier, you could immediately consult your electronic calendar. These quick external references can free up the mind for more thoughtful work. Instead of having to remember minor details of whereabouts and shopping lists, the internal memory cycles can be put to use making associations, drawing entailments, and otherwise exercising critical thinking skills.

The multi-step format of the model allows for the recognition and re-incorporation of the external stores. In this way, external memory is external storage until such time as it is verified and authenticated by the mind based on the processing model as a memory extension. Although extended memories are stored externally, once activated into the Converter/Interpreter or recall phase, they become part of the larger set of memories, cross-referenced and re-contextualized. In a functional sense, once past the Converter/Interpreter gloss for salience, external memory is subjected to the same cued recall as is internal memory, going through recursive processing, free to consult external memory at any given time.

The CMM’s schema depicts the nature of Santiago Arango-Munoz’s (2013) theory about two facets in the mental extension and distributed cognition debate particularly related to memory. He labels these the “selection problem” and the “endorsement problem”, both of which arise as a result of structural problems related to mental scaffolding (Arango-Munoz, 2013, 135). The selection problem reduces to a cognitive choice on behalf of the agent as to whether or not to solve a problem internally or externally. The endorsement problem arises when the agent is faced with either accepting or rejecting the solution, one that was retrieved either internally or externally. Arango-Munoz propose the answer to these problems in terms of metamemory and metacognitive feelings (2013, 135).

The selection and endorsement challenges arise as a result of an epistemic instability arising from the use of memory enhancing external resources. This mental scaffolding, or the use of both internal and external resources, can, in some instances, complicate memory in terms of extra decision processes over which type of information to use and when and how to endorse it (Arango-Munoz, 2013, 142). The agent appeals to metamemory as an evaluation tool to assess the metacognitive feeling concerning the memory task, subsequently choosing to seek the information either internally or externally. Arango-Munoz explains, "When confronted with a memory task, metamemory evaluates whether the information can be internally retrieved from a subject's internal memory store or the subject has to resort to an external strategy such as consulting a dictionary or the Internet. This evaluation generates a positive metacognitive feeling when the information is likely to be internally retrieved. This metacognitive feeling concerning memory retrieval has traditionally been called the feeling of knowing: it motivates the subject to try the internal mental action of internally recalling the information" (Arango-Munoz, 2013, 142). Arango-Munoz attributes many of the selections we make to the guidance of our "metacognitive feelings" at any given time. He states, "Metacognitive feelings are phenomenal experiences that point towards mental dispositions of the subject such as knowledge, ignorance, or uncertainty" (2013, 142).

Arango-Munoz suggests that both the selection and endorsement problems relate to functional stages of memory retrieval and scaffolding in terms of efficiency at the selection stage in knowing when to choose the type of resource. That is, inner searches may take longer to find the information, whereas external searches cost more in terms of sensory-motor resources. As well, Arango-Munoz notes that there are additional costs incurred to verify the information, whether it be internal or external, before using it as a premise for further judgements (2013, 142).

Arango-Munoz also states that in the case of Otto's notebook, A. Clark and D. Chalmers' (1998) past endorsement criteria resolves both the selection and endorsement problem in that particular case. The selection problem is resolved via the use of metamemory and metacognitive feelings as would be functionally manifest in the C/I.

5.2.1.2 Operation in a Complex Memory Task

The CMM can ease John Sutton's (2010) objectification concerns about extended memory due to the dual mechanistic pairs involved in its formulation. That is, the fallibility and inconsistency of human memory are addressed in the model, since all external prompts or memories go through the internal mind processes as do internal memories. Once the encountered external information passes salience via C/I module, the information can be used in reconstructing the original memory. Minimally a new memory is formed containing the event of encountering the information and determining that it is yours. Since the CMM processing is recursive, the depth of internal processing is a factor. Shallow processing need not get past the Buffer Pool, while deeper processing will exercise XREF and LTM.

The model also shows agreement with Sutton's objectification challenge in that if someone shortcuts directly to the "cloud", bypassing the internal processing and thus taking the external information at face value, previously endorsed records remain unchanged until retrieved (Figure 5). This is in line with Sutton's "container view" of memory in that an external memory is not *completely* trusted without first comparing to what the mind internally already knows about it. Sutton holds that biological or internal memory is non-preservative and subject to forgetting, while external memory is held as "discrete stable items", unchanged until retrieved. The CMM acknowledges this claim, and while it is true that externally stored memories do not “forget”, when such memories are encountered as a stimulus, the mind re-introduces their meaning by re-incorporating them into its associative network.

Remembering as such is a process of information being recognized, passing the salience check of the Converter/Interpreter, and proceeding through the rest of the recall phase in search of associations to that information. While external memory is subject to damage and loss, as noted in EMH arguments, this is no more problematic that internal memory decline due to accident or mental impairments such as dementia (see A. Clark and D. Chalmers, 1998). The external memory itself is not subject to forgetting in the same way as an internally stored memory, however the internal associations for that memory *are* exposed to imperfection. For instance, the content of my handwritten recipes does not change but my internal recall of flat meringue resulting from using a plastic mixing bowl to beat the egg whites might be forgotten. Based on my past experience making meringue I could have written in a reminder in the method section of the recipe, or as many of us do, bypassed this step figuring I would remember to use a glass bowl in future. Likewise, I use my calendar to remind me of my nephew’s birthday, but this does not prevent me from choosing identical birthday cards two years in a row. I remember his birthday and to buy him a birthday card, but I don’t up front recall the actual content of the cards I choose each year. My memory of his birth date is intact but my recollection of the card I gave him is imperfect.

T. Pathman, Z. Samson, K. Dugas, R. Cabeza, and P.J. Bauer (2011) explain that although autobiographical and episodic memory are closely related, they are most often studied independently, resulting in little understanding as to the breakdown or divisions or overlaps of autobiographical and episodic memory. The commonality between the two types of memory is the fact that both types deal with recollection of personally experienced events and their contexts, with some psychologists viewing autobiographical as a subset of episodic, with the two having different time scales. Still other debates arise in terms of the developmental aspects of both types of memory, using children and adult participants. Pathman et al. explain that despite the categorization differences in these types of memory, “a paradigm introduced in the adult literature allows for direct comparison between episodic and autobiographical memory retrieval” (2011, 826). Pathman et al. ran a study to compare the development of autobiographical and episodic memory in children and adults, using a series of photographs that the participants either took themselves, saw someone taking, or neither took nor witnessed the photograph taking place. All participants attended a photo-taking activity in a museum, then were asked to classify photos as ones they took, viewed others taking, or that were novel. The aim of their study was to determine the development of episodic and autobiographical memory, to shed light on the somewhat disputed interrelation or interdependence of the two types of memory. According to the findings of their study, the conditions of encoding for autobiographical and episodic memory differ, in that “episodes that become autobiographical are encoded differently from episodes that do not” (Pathman et al., 2011, 833). Pathman et al. found that autobiographical encoding involved: active participation in the environment; transitions between rooms and contexts; and temporal spacing between events. By way of contrast, episodic encoding involved: viewing items on a computer screen; sitting in one location; and minimal spacing between events (Pathman et al. 2011, 833).

The research of Pathman et al. (2011) shows a shallower encoding of episodic memory over autobiographical due to the additional autobiographical encoding elements of active participation, physical location, and temporal spacing. Episodic encoding conditions involve the more passive viewing, sitting, and minimal temporal event spacing. The CMM expresses such encoding and retrieval with both internal and external memory. The CMM eliminates confusion, explaining how distinct components work together in a coherent, operational, and distributed system. It contains necessary mechanisms involved in recognizing its own memories. The CMM shows the memory recall and matching in action. It is a process view of the conceptual search, sort and file mechanisms involved in the way the mind treats memory. When the conclusion is not immediately obvious, the model shows how the mind reaches for more, either inside or outside. By applying the effects of practice, the CMM can allow tracing of the consequences of going outside or inside, exercising one path or the other.

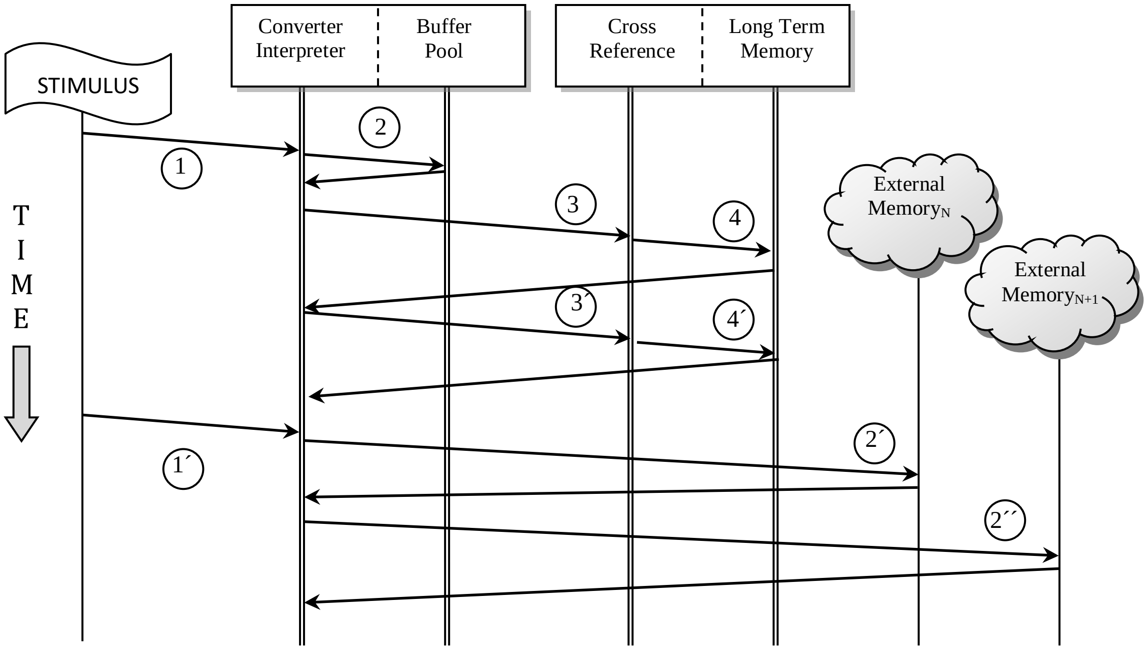


Figure 5 – Complex Memory Task

This is illustrated with the test of a doctored photograph and the amount of recognition and deeper processing required for validation as illustrated in Figure 5. As the subject, you would scan the photo (Step 1), for immediate inconsistencies using the Converter/Interpreter and Buffer Pool (Step 2). If you were not able to immediately dismiss the photograph as false, you would seek the increasingly finer details of the photograph using the Cross Reference (Step 3) and Long Term Memory (Step 4), in search of supporting evidence one way or another. You might be able to determine a date and time, then following the sequence (Steps 3´ and 4´), narrow down the finer clues associated with your daily routine. Alternatively (Step 1´), you are free to consult various forms of External Memory (Steps 2´ and 2´´), such as a personal calendar or personal notebook or another mind, thereby using external memory to remember the context. For example, when presented with a photograph of yourself standing by the Eiffel Tower and asked whether this could be a picture of you, you perform a first gloss in the form of a judgement of familiarity, replying in the affirmative that it is entirely possible, since the photo looks generally accurate. So you see yourself in the photo, and based on broad matching of elements you conclude that it could a valid photograph. This is evidence of the Converter/Interpreter (C/I) mechanism in action, scanning an encountered piece of information for immediate general accuracy, that is, no overt contradictions are apparent.

Next you are asked if this is truly a picture of you, opening up the possibility of tampering, such as with Photoshop. You notice that you are about the right age in the picture, the season is approximately correct (you had visited in autumn), and that you are wearing the new coat your spouse bought for you in London before boarding the Eurostar to Paris. Again, you deem the photograph is possibly accurate. Prompted to look for further assurance of accuracy, by cross referencing your catalogued associations you look for further clues in the scene, trying to match them with your internal longer term memories. This time you recall that you did not wear the coat having returned it to the vendor in London shortly after purchasing it, and picking up a new one in a slightly larger size on the way back from Paris; you did not have the coat with you in Paris after all. Other memories flood in, about arriving in Paris during inclement weather and wishing that the coat had fit and you could have brought it along, instead purchasing a similar less expensive version for short term use until your return to the UK. You conclude that the photograph is modified, more accurately noting that an image of you a week later posing in Trafalgar Square was used in that picture as you are pointing to the buttons on the front, proud of the comfortable fit. Had you consulted your iDevice, your extended memory would contain such as the email you wrote, the calendar entry you made regarding the purchase, return and picking up of the new coat.

Due to its continually deeper searches from the Buffer Pool and into LTM where the memory is stored using associative elements, the CMM can be used to depict what H. Rice and J. Rubin (2009) describe as a tendency toward multi-perspective retrieval. First-person perspective is that of recalling the memory from your original point of view. Third-person perspective tends towards an objective recounting or narrative of the situation in which the person recalls a scene of the event. The CMM's allowance for distributed memory bodes well with multiple perspective shared recall. Rice and Rubin (2009) analyse and research the differences in *perspective* conceptualization across various studies. For instance, some studies maintain that first-person and third-person perspective retrieval are possible at the same time, while other studies support singular retrieval. They conclude that in fact the two perspectives can be experienced during memory recall of events, and "the experience of the two perspectives correlated differentially with ratings of vividness, suggesting that the two perspectives should not be considered in opposition of one another" (Rubin and Rice, 2009, 877). For example, recalling a childhood memory of being on a beach can bring to mind the beach setting, the sun, surf and sand through the eyes of yourself as a child. From a wider perspective, perhaps through the eyes of the adult you are now, you could see yourself as a child in the beach scene. Furthermore, the perspective can shift within the same recall event. Rice and Rubin also found that robustness and memory age were correlated, in that vividness and tendency toward more of a first-person perspective recall occurred with more recent memories, while third-person perspectives were more likely to happen with older memories (2009, 888).

5.3 The CMM and Milkowski's checklist for computational processes

> Milkowski's checklist for computational processes requires that all of the following are satisfied:
>
> 1. The initial and final states of the process are causally linked
> 2. If there are stages in the processing, they correspond to the stages of the system's activity
> 3. The system is relatively isolated
> 4. The system supports interventionist causation
> 5. The system is organized
> 6. The mechanism's constitutive levels are at the bottom
> 7. The trajectory of causal states corresponds to the computation model
> 8. The computation model is complete
>
> (Milkowski, 2013, 81-83)

As detailed in the following description, the CMM may be seen to satisfy the philosophical elements of Milkowski's checklist for computational processes.

Regarding point one, which requires that the initial and final states of the process be causally linked, it has been seen that the process flow between the functional blocks of the CMM occurs in a directly connected fashion from the initiation in the C/I functional block to the next functional block until the final state of the process is reached. At no point is the process flow unaccounted for, therefore satisfying the causal linkage between initial and final states.

Regarding point two, which requires that the stages in the processing correspond to the stages of the system’s activity, the stages of processing in the CMM correspond to the operation of the functional blocks. As a result the processing stages are inherently subsumed in the operation of the CMM’s functional blocks, therefore satisfying the requirement.

As discussed earlier with respect to Milkowski’s mechanistic model, there are to be provided three distinct levels of explanation for a mechanistic account as shown in Figure 6. These levels are the Contextual Level, the Isolated Level, and the Constitutive Level. The Isolated Level is where a mechanistic model of a system is situated. The Contextual Level comprises the environment that the model is situated in, and the Constitutive Level comprises those mechanisms which realize the system elements at the Isolated Level.

CONTEXTUAL LEVEL	Environment
ISOLATED LEVEL	Concepts
CONSTITUTIVE LEVEL	Physical

Figure 6 – Levels of the Mechanistic Account

With respect to the third point, which requires that the system be relatively isolated, and more specifically that the boundaries of the system roughly coincide with those discernible at the constitutive level of the mechanism, the CMM is bound by the sum of the mechanisms within the body and artefacts that the body handles. The body and the employed artefacts are readily distinguishable at the constitutive level, therefore satisfying point three.

With respect to the fourth point, which requires that the system support interventionist causation, the test is whether it is apparent that a change in the input stream will be reflected in the appropriate changes of the whole computational process. It is evident from the descriptions of operation via the process flow diagrams, that a significantly different stimulus will distinguished by the C/I function and XREF functions and will thereby produce appropriate changes in the results of the whole process, therefore satisfying requirement number four.

As per the fifth point there is the requirement that the system is organized, specifically that it is more than a simple aggregation of coincident parts. This fifth point has been satisfied by way of the interoperability of the parts of the CMM having been described at length, and it has been demonstrated that the interoperability is what produces the required computational function, which is memory.

As per the sixth point there is the requirement that the constitutive levels are at the bottom of the model. As described previously and explicitly illustrated in Figure 7, the functional processes of the CMM at the isolated level have respective corresponding mechanisms of a psycho-biological nature at the constitutive level. The model does not make recourse to anything further, therefore satisfying point six.

Concerning the seventh point there is the requirement that the trajectory of causal states corresponds to the computational model.   As described previously, the trajectory of operations as depicted in the process flow diagrams corresponds to the CMM computational model in action, at the conceptual level. Therefore, future work will require further mechanistic modelling of the components at the constitutive level.

Finally, concerning the eighth point, there is the requirement that the computational model be complete. As depicted in Figure 7, the CMM has explicit mappings to mechanisms at the constitutive level from each of the functional processes at the isolated level. The functional processes at the isolated level have been demonstrated to account for memory functions of short-term recall and long-term recall. Philosophically, the model is poised to accommodate brain mechanisms as they become known.

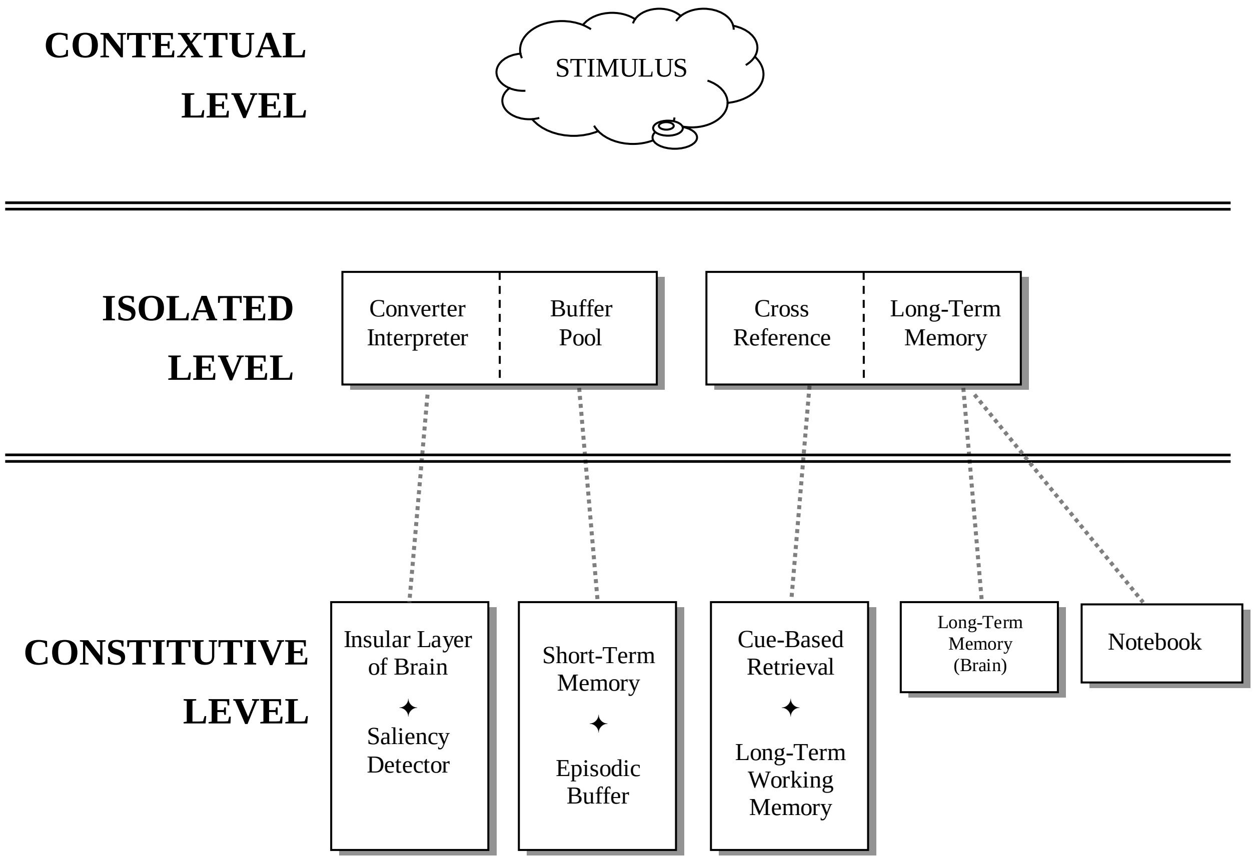


Figure 7 – The CMM under the Mechanistic Account

Insofar as a computational model of memory accounting for these processes the CMM satisfies point eight. The CMM may be seen to satisfy most of the requirements of Milkowski's checklist for computational processes.

5.4 Implications for HEC/HEMC debate

Contextually, the CMM encompasses general “cognitive” mechanisms and can include the environment (see Figures 3 to 10, this Chapter). Extended mind theory holds that human memories can be stored outside the head. Computational theories facilitate modelling the mechanisms of the mind, as well as depicting the relations between these mechanisms. Combining both of these views with respect to human memory yields a processing schema of the architecture and mechanisms both in the head and that sometimes extend into the environment, which serve to cross-reference, categorize and sort memories into, at the very minimum, short and long term. The model satisfies the past endorsement criteria by way of its C/I mechanism, and fulfills functional parity requirements for externally stored memory to be considered an extension of the mind by way of the multiple realizability feature of an adequate mechanistic account (A. Clark and D. Chalmers, 1998).

5.4.1 Response to Extended Mind Hypothesis Challenges

The CMM addresses the challenges to past endorsement (F. Adams and K. Aizawa, 2008, R. Rupert 2004, 2013), processing specifications (Adams and Aizawa, 2009) and parity (M. Sprevak, 2009) by way of its design.

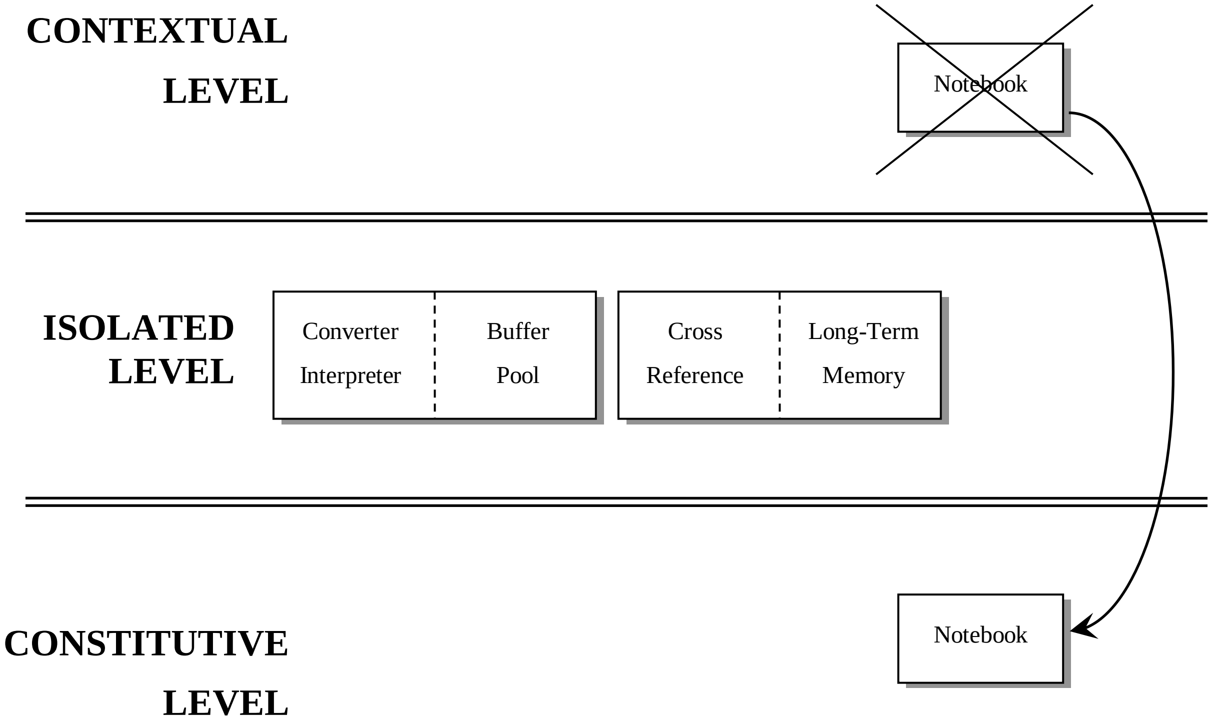


Figure 8 – Boundary Confusion and Category Errors

A boundary is a demarcation between levels of explanation. In terms of levels of explanation there is a demarcation between the isolated and contextual level as well as a boundary between the isolated and constitutive level.

Referring to Figure 8 it may be seen that the CMM is at the Isolated Level and Otto's notebook is in the Constitutive Level on the other side of a particular boundary. Things above the upper boundary are part of the Contextual Level while things on the other side of the lower boundary make up the mechanisms that constitute elements of the system. The category error made in objections to the Extended Mind boundary entail placing the notebook at the Contextual Level and not where it mechanistically realized, which is at the Constitutive Level as depicted in Figure 8. Contrariwise, with respect to Figure 8, Complementarity theory may be discerned as operating at the constitutive level in terms of characterising the notebook as but one of multiple ways of realizability.

5.4.1.1 Identifying Boundaries

The challenges related to past endorsement are resolved by way of specifying boundaries and being able to recognize what memory content is mine. The CMM's C/I mechanism helps to answer the boundary issues raised by Frederick Adams and Kenneth Aizawa (2010, 79) and related objections concerning cognitive bloat (Robert Rupert, 2004, 401-405). Realized with the insula brain region that acts as a scan for salience, the C/I mechanism serves as a form of orientation so that your mind can go where the C/I recognizes your landscape cues. The C/I is a functional answer to the boundary question, in that this mechanism is able to discern previously endorsed content.

This boundary recognition feature answers Adams and Aizawa's coupling question as to how we know what to couple and what counts as part of my cognitive system. We recall from Chapter 2 how Adams and Aizawa claim that the group of arguments for mind extension pay insufficient attention to plausible distinctions between causal connection and causal constitution. Adams and Aizawa argue that just because some process X is part of a system, does not mean it does the work of the system (2008, 107). For example, Adams and Aizawa challenge that although the interaction between the brain and the pen and paper can provide the basis for a causal process, in that the brain uses the pen and paper when performing a cognitive process, this does not mean that the human, pen and paper together constitute a causal process, just that the pen and paper are used to facilitate cognitive processing. Furthermore, Adams and Aizawa maintain that although a human, pen and paper can constitute a system that together perform X, it does not follow that every component does X.

At the root of Adams and Aizawa's objections lies a confusion between types of boundaries. Their challenges to EM can be elucidated by way of the mechanistic account and the CMM. While Adams and Aizawa correctly claim a difference between causal connection and constitution, there is a confusion between different boundaries they are using. That is, there is a boundary between the isolated and contextual levels as well as a boundary between the isolated and constitutive levels. In the first case, a notebook at the contextual is any notebook. In the second case, a notebook at the constitutive level is Otto's notebook. As shown in Figure 8, substituting the first type of notebook for the second type amounts to a category error. Adams and Aizawa correctly note, that a human using pen and paper do not constitute a cognitive process and that not every system component does the X the system does. Establishing the boundary as the one between the isolated and constitutive levels helps to clear up confusion about what is part of the system and what is outside of it.

Under Milkowski's schema, a function at the conceptual level is constituted by the mechanisms at the level below. In the event that the constitutive level is the bottommost level, then the physical parts which instantiate the function at the conceptual level immediately above, would also constitute the function. For example, consider the function of locomotion for a person who is missing the part of her left leg below the knee. For this person, the function of locomotion could include sub-functions of hopping and crawling but not walking. Her hopping function would be instantiated by using her right leg, and the crawling function would be instantiated by using both arms and her right leg. In the event that this person was provided a prosthetic leg she could add the sub-function of walking to her locomotion function. The walking function would be instantiated by her right leg, and the remaining portion of her left leg fitted with the prosthetic leg. Her walking function would be constituted at the constitutive level by what instantiated it, namely her right leg, the upper portion of her left leg, and the prosthetic leg. Under this modelling schema there is no ambiguity about the prosthetic leg being part of the walking function.

In the more general case for a function *f* the characterization would be that the function *f* is constituted by those mechanical parts which are necessary and sufficient to instantiate the function. The collection of those mechanical parts which instantiate the function define a set having a boundary. Inside the boundary are the parts which instantiate the function, and outside the boundary lie all other parts. This particular function-constituent boundary could be challenged in one of three ways: it could be redrawn to include further parts; it could be redrawn to exclude existing parts; or it could be redrawn in respect of an additional criterion.

In the first case there does not exist a criteria as to what additional parts should be included or not included, which renders it impossible to distinguish alternatives to the boundary. In the second case, the removal of a constitutive component causes the function to fail. The exclusion of a necessary component obviates the existence of the function, that which defined the boundary in the first place. In the third case, specifying an additional criterion could result in the boundary being adjusted to exclude certain constitutive parts or include other parts, but would do so only to accommodate this additionally defined criterion, which is unnecessary to the operation of the function. The addition of the criterion, and the change in position of the boundary relative to constitutive components must therefore be present due to intentions other than those necessary to instantiate the function.

The function-constituent boundary established by Milkowski's schema (contextual, conceptual and constitutive levels) in conjunction with Russell's type theory (entities at a given level are built exclusively from the entities of preceding types, those lower in the hierarchy) could be used to resolve the boundary identification problem. This is because for a given function at a particular conceptual level, the boundary includes those functions at the preceding constitutive level. Reapplying this formulation while moving down one level in the hierarchy continues the process of elaborating the boundary to include those constituents of the level beneath the initial constitutive level. This recursion of moving downward can conclude when the modeller has reached a sufficiently low enough constitutive level for the modelling purposes. For modelling of some functions it may suffice to proceed to an object level, for other functions it may be necessary to proceed to a biochemistry level.

The CMM is a computational model according to Milkowski's schema, in conjunction with Russell's type theory, of the function of memory. This function is modelled at the conceptual level by four entities: the converter/interpreter, the buffer pool, cross-reference module, and long-term memory. As per Figure 7, at the constitutive level the posited mechanistic component for the converter/interpreter is the insular layer/saliency detector; for the buffer pool is the short-term memory regions and episodic buffer in the brain. For the cross-reference module there is the cue-based retrieval and long-term working memory and for the long-term memory the long-term memory regions, and in Otto's case Otto's personal notebook.

As per the function *f* being constituted by those mechanical parts which are necessary and sufficient to instantiate the function, the function of long-term memory in Otto's case would include Otto's personal notebook. The long-term memory function is part of the instantiation of the higher level function *memory* and Otto's notebook is a part of his memory. As the function *memory* is a sub-function of the function of *cognition* then Otto's notebook, as a constitutive part of his memory would be part of his cognizing function.

Adam's and Aizawa could respond to this chain of reasoning by reiterating their claim about what they characterized as "some broader notion of the cognitive." They note "that a human with pencil and paper has greater reasoning abilities and greater mathematical abilities than a human left to her own brainy devices. Similarly, when Otto avails himself of a notebook to remember information that is valuable to him, he becomes cognitively more than the sum of his parts, paper, and pencil. Much of Clark can be viewed as an elaboration of the kinds of ways in which human cognition will be transformed into some alternative kind of cognition through increasing reliance on tools" (Adams and Aizawa, 2010, 29).

Adams and Aizawa are explicitly revealing that in respect of their arguments regarding cognition they are not distinguishing cognition *per se*, but a particular subclass of cognition, namely *human cognition*. They concede that the "reliance on tools" transforms a particular kind of cognition, human cognition, into an "alternative kind of cognition".

One could respond to Adams and Aizawa that their additional criterion of "human cognition" corresponds to the additional criterion of the third case of redrawing the boundary considered earlier. More explicitly, Adams and Aizawa's criterion will serve to redraw the boundary so as to exclude elements used to instantiate any cognitive function insofar as it extends beyond the head. This is not an argument against extended cognition *per se*, it is a refusal to admit the consideration of any cognition involving components outside the head. In conclusion, the application of Milkowski's schema in conjunction with Russell's type theory, such that objects of a given type are built exclusively from the objects of preceding types (those lower in the hierarchy) will result in the generation of a boundary which can identify which elements in the real world instantiate a function. The implications allow the answering of questions regarding whether extra-corporeal artefacts may be considered part of i) the function of memory, and by logical extension ii) the function of cognizing – both in the affirmative.

Using the model to show how a boundary is established for my own content can be used to confront and dismiss Rupert's challenges regarding granularity in which he argues that HEC requires such a coarse grained account that its explanations are reduced to HEMC equivalent (2004, 418-421, 2013, 33, 40). Rupert's arguments amount to cognitive bloat and boundary issues, both of which can be answered by way of the CMM's C/I mechanism and its fully described mechanisms. We recall Rupert's argument that unless it can be shown that HEC offers superior explanation of cognitive phenomena, all else being equal, cognitive science should endorse HEMC over HEC, due to HEMC's more conservative methodology (2004, 395). Rupert contends that the HEC theorist faces a dilemma with regard to either acceptance or rejection of prior conscious endorsement, in that on the one hand acceptance of such past endorsement would collapse HEC into HEMC, while on the other hand rejecting past endorsement leaves weak criteria that can too easily satisfied (Otto's notebook being a constant in his life, always available to him and its contents automatically endorsed). Rupert argues that the functional requirements for HEC are motivated by empirical considerations, a requirement that leads to boundary issues as to what constitute external beliefs (2004, 422).

In response to Rupert's challenges, the mechanistic account can be used to clarify boundary issues, and the CMM's C/I mechanism provides a scan for salience so I can recognize my own external content. Rupert's concerns about past endorsement and HEC's functional requirements can be appeased by way of a mechanistic explanation and ensuring that mechanisms are realized at the appropriate level.

5.4.1.2 Mark of the Cognitive

The mechanistic view of the CMM depicts levels of processing within a system, which can be used to expose Adams and Aizawa's (2009) system versus process challenge as a category error. Adams and Aizawa's challenge that information transfer is not sufficient for cognitive processing status, for example, just because together, a human and pen and paper form a cognitive system, does not mean there is cognition present in the pen and paper (2009, 83). However, by way of its structure, the mechanistic approach shows how Adams and Aizawa are mixing levels when arguing against the processes and status of a cognitive system. That is, they are looking to the overall system in order to find processes within a mechanism, when in fact they processes they seek are at the isolated level and not in the mechanisms themselves. For example, there is no arithmetic going on in the "%" button of a calculator. The arithmetic is found in the calculator's program, not in the gears of the calculator's mechanisms.

5.4.1.3 Parity and Functionalism

An advantage of a mechanistic view is that models can be compared on similar levels of description. Mark Sprevak argues that HEC's functionalism is too coarse grained and admits too much, so much so as to form its own counterargument (2009, 10-16). In answer to the granularity challenges, the CMM's C/I module together with the multiple realizability and complete descriptions of an adequate mechanistic account, resolve the boundary issue in that I can know what content is mine and where the content can be located. It can be shown how Sprevak's challenge fails when presented with a mechanistic view because Martian intuition violates respecting the isolated and constitutive levels. The CMM depicts the isolated and constitutive layers of human memory. Since the Martian and the human are two different models, they can be properly compared only if the Martian is also modelled in terms of comparable explanatory levels. At the isolated level the Martian has memory, but there is no Martian constitutive layer to show how this memory is realized, and so the Martian and human cannot be compared according to the equivalent criteria.

As discussed in Chapter 3, Michael Wheeler's extended functionalism view combines functional equality of properly causally arranged internal and external elements included in extended cognition, with the multiple realizability of type-identified generic cognitive processes in two forms, inner and external, to yield an *extended functionalism* (Wheeler, 2010, 248-249). Wheeler maintains that the multiple realizability characteristic of extended functionalism eliminates chauvinism of mind and allows, in principle, for appropriately functionally organized Martians, robots and other beings to have mental states (2010, 247-248). The isolated and constitutive layers of the mechanistic view of the CMM address Wheeler's concerns regarding HEC's potentially chauvinistic bias or benchmarking on the inner in that the constitutive layer is involves a functional realization of a process at the isolated level. As indicated above with respect to Sprevak's challenge, Martian memory could be modeled under a mechanistic account. The three level mechanistic model is compatible with Wheeler's more general and multiply realizable form of functionalism. Processes described at the isolated level can be–realized in different forms at the constitutive level.

5.4.1.4 Computational Approach

Robert Wilson's argument for wide memory (2000, 40-43) supports an externalist account of cognition and memory in terms of computation. The CMM is a realization of a computational approach to memory and cognition. A computational model that is described under a mechanistic view establishes criteria for what is constituted by the cognitive system in its environment. Those processes that are realized in mechanisms have been fully described causally within the system. Processes that are not fully described fall under mechanistic schemas until sufficient information is acquired for a complete explanation.

Adams and Aizawa claim that cognitive processing is but a narrow form of information processing and challenge the computational account as being too broad (2008, 89). They argue that if cognition is just any sort of computation, then we would have to admit things that are not cognitive, for instance, brains, bodies and environment as in E. Hutchins' (1995) navy ship example and potentially personal computers. Under the mechanistic view, any brains, bodies, environments or personal computers would qualify as part of the system only if they can be constituted using the multiple realizability feature of a completely described adequate mechanistic model.

5.4.1.5 Complementarity

Complementarity arguments claim that external resources are co-opted because of their differences, and these differences serve to augment our inner capabilities (John Sutton, 2010, 197-199). Richard Menary's (2010, 230-234), Kim Sterelny (2010, 471-477, 2003, 243, 252), and Paul Loader (2013, 167-174) question the way in which resources are chosen and how these resources are used. Menary's integration theory suggests we engage with external resources in a complementary manner to enable us to do more. Sterelny claims a scaffolding approach to using external resources, suggesting we can go beyond single user resources to a multi-agent focus. Loader proposes an enactive view in which memory is portrayed as an act of remembering.

The CMM is compatible with complementarity approaches in that external memory can come in the form of other minds, multiple minds can share the same external resources, and group memory can also involve group members cuing off each other during acts of remembering. These scenarios are depicted in the next section wherein Figures 9, 10 and 11 provide process flow diagrams of distributed, transactive, and collective recalls as well as a recall from artefacts, respectively.

5.5 Broader Applications of the Model

The CMM can depict recent developments in the philosophy of memory research, specifically, distributed, transactive and collective memory.

5.5.1 Operation in Distributed Memory Context

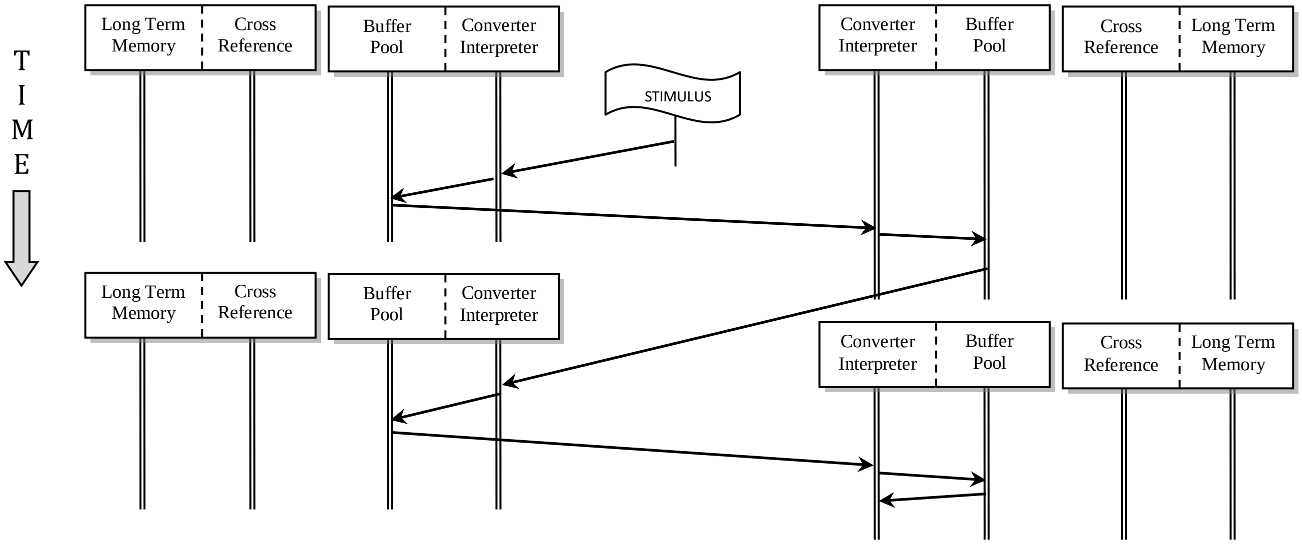


Figure 9 – Distributed Memory

Other minds act as successive cues for each other. The environment in which recall occurs plays an important role.

An example of a distributive memory context is that of actors in a play, each one having memorized the lines of their particular character, but not the whole play. This is depicted schematically in Figure 9. These lines are cued and delivered based in sequence by cueing off the lines of the other actors. In this example no single actor knows all of the other actors' lines, yet individually and collectively they make up a complete dialogue (John Sutton, 2010, 2012). Edwin Hutchins' navy ship example is well-known in the area of group cognition in which each person on the bridge is knowledgeable of their own task, each of which is required at the same time in order for the ship to operate smoothly (Hutchins, 1995).

5.5.1.1 Distributed remembering

Nils Dahlback, Mattias Kristiansson, and Fredrik Stjernberg (2013), describe memory research in elderly persons with a focus on the process of distributed remembering and its effects on overall cognitive function. They note that an analysis of remembering, within the context of everyday practices, should include the whole person, as well as the settings of a particular activity (2013, 17). Dahlback et al. draw on a scenario of creating a list, and then going shopping for those items, to explain the act of distributed remembering. They explain, "The shopping list is in a sense the plan for the activity. Therefore, when we examine extended memory systems, we need to view the interaction between agent and external structure and the properties of the activity from two perspectives, the task of the agent when using the artefact, and the properties of the system comprising of the agent and the artefact" (Dahlback et al., 2013, 159). Their analysis of the way in which the subject engages with their external environment indicates that the external artefacts are more than just providers of "faithful storage. The artefacts play a key role in the nature of the subject's coordination with her environment so that external memory is assembled as we go. "The process of remembering through an external world is also a constructive matter similar to internal memory processes. We select, abstract, interpret and integrate information through structuring the external world" and further, "the nature of the coordination between artefacts, people and routines determines this preservative function"

(Dahlback et al., 2013, 162). Though we use external aids to preserve information, there is no guarantee that we will remember, in fact, externally stored information can have the opposite effect, inducing forgetting.

Dahlback et al. suggest that the external world must be handled in a proper way so as to make efficient cognitive use of our surroundings (2013, 163). They summarize that the quality and nature our interaction with our world in terms of external memory is “a function of the characteristics of the task and the agents’ abilities”. Applying this insight into studying the effects of distributed remembering on the elderly, Dahlback et al. conclude “the changes observed in memory in elderly people is not only or primarily seen as a compensatory process where what was once internal now becomes external, but instead a shift in balance and shift in methods between the internal and external contributions to the process of remembering" (2013, 163).

5.5.2 Operation in Transactive Memory Context

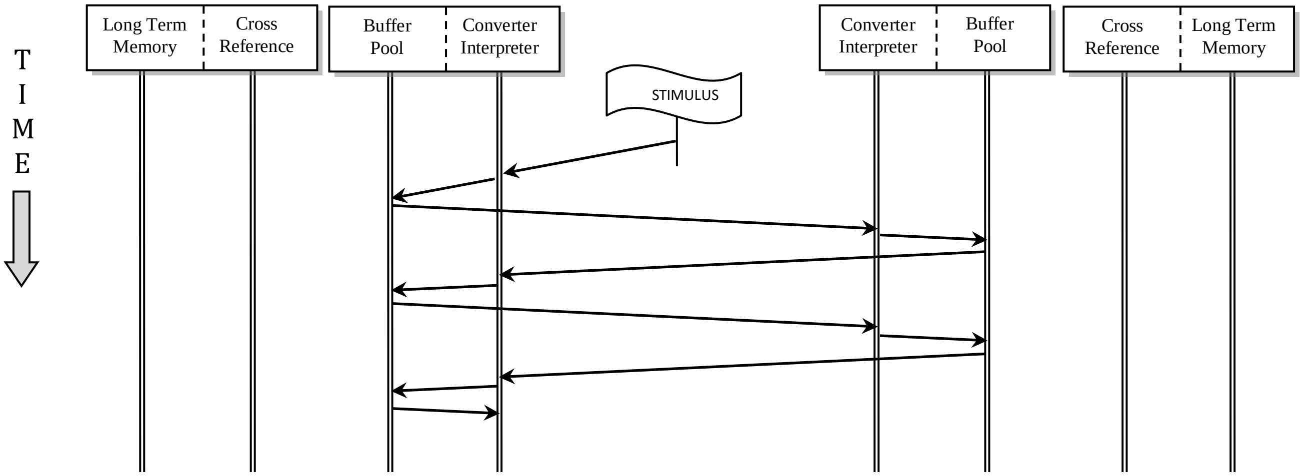


Figure 10 – Transactive Memory

Each person in a group recalls a piece of the group experience, aiding and prompting each other’s recall; possibly finishing each other’s sentences. This is depicted schematically in

Figure 10. The added complexity of adding another connection to get transactive memory can be seen beneficially as an expansion of individual memory or as a possible source of confusion and error (D. Wegner 1986). A typical example of transactive memory would be a long term married couple recalling a shared vacation experience in which both spouses were at the same place and sharing experiences. More than cueing reminders for each other, the couple fills in the memory "gaps" for each other while recounting their experiences (John Sutton, 2010, 2012).

M. L. Meade, T. J. Nokes, and D. G. Morrow (2009) show how domain experts display similar memory encoding strategies, similar output at memory retrieval and that experts encode differently than novices. Conducting empirical studies with a group of pilots, whose level of expertise is very specific and must be accessible quickly, they found that not only did the level of expertise benefit collaboration, non-experts actually served to disrupt collaboration. They identified the predictive factors of the success of group collaboration in terms of the benefits of discussion at the same level of expertise, the verbal conversational mechanisms related to collaborative skill and domain knowledge, and verbal communication back and forth and repeating others' contributions. Where the group members were at a comparable skill level, the verbal exchanges within the group moved along with ease. On the other hand where at least one member was at a more novice level, their participation interrupted the thought processes of the experts and in fact slowed down their thinking (Meade, Nokes and Morrow, 2009, 41-44). This research identifies the factors that predict either inhibition or facilitation in group collaborative memory tasks, something that can be reflected in the CMM in action. For example, with transactive and distributed group memory, the CMM depicts the use of mainly the lower levels of processing for the individuals, for the most part not having to resort to deeper learning areas. The facilitation of collaboration based on similar levels of domain expertise, as found by Meade, Nokes and Morrow's (2009) is explicated by the CMM in action for group memory tasks, since like-minded groups of similar levels of expertise use the same depth of individual processing. A group member requiring deeper knowledge would have to resort to the knowledge of other members and be carried along by the group, slowing it down.

5.5.3 Operation in Collective Memory Context

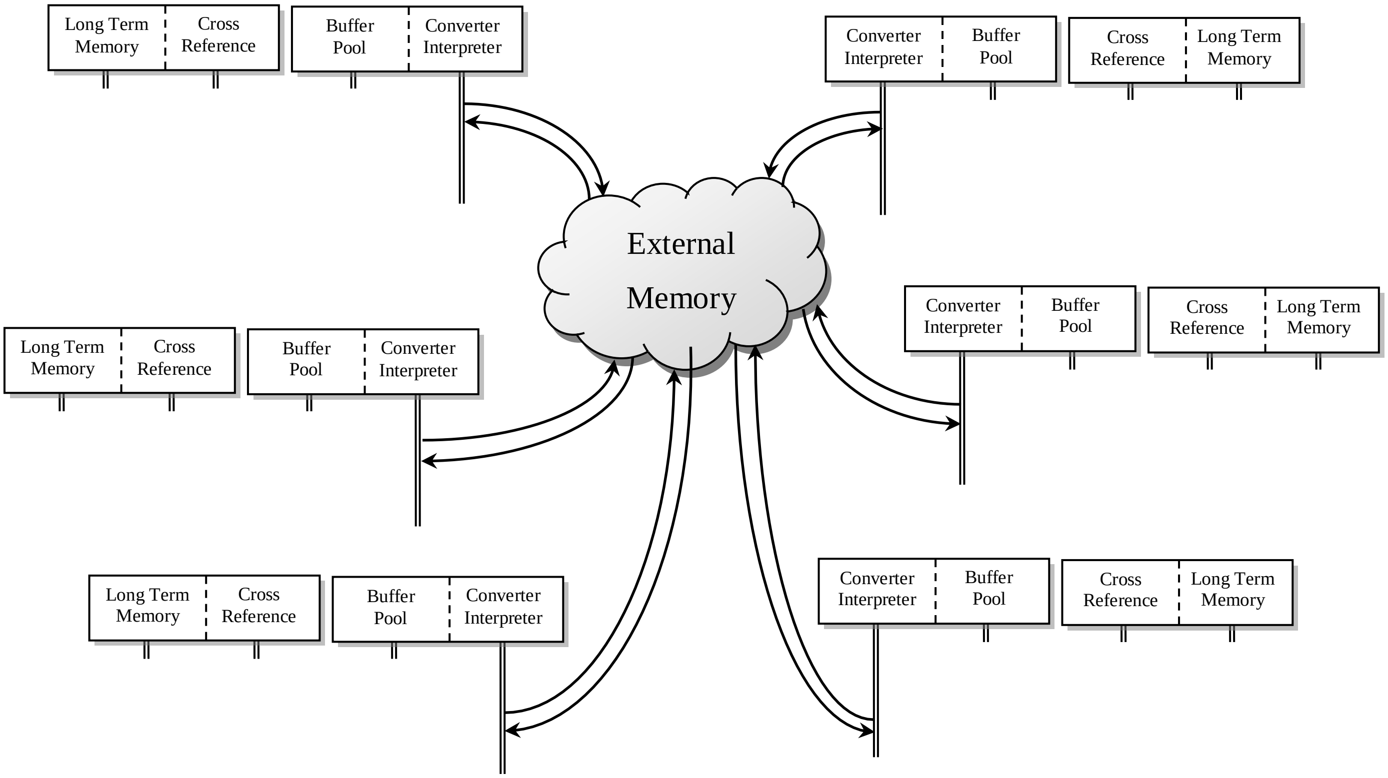


Figure 11 – Collective External Memory

An EXTERNAL MEMORY is used as a common reference for multiple minds, emphasizing external search while minimizing internal search.

Referring now to Figure 11, it may be seen that the CMM applies to both a standard example of collective external memory, such as a document for a group project that was created and so previously endorsed by the group, as well as a modern example of a Cloud centered, shared information source taken at face value, such as a Wikipedia entry. The utility of this depiction of the CMM in action is that it provides a basis for evaluating the effects of collective external memory on the individual members of the collective.

5.6 Summary

In this section I have demonstrated that applying EM objections to a philosophical model helps to illustrate the nature of arguments that improperly cross logical levels. I have also demonstrated how a philosophical model of memory that conforms to the mechanistic account can be used to illustrate how external artefacts including other minds work together as forms of extended memory.

Under the mechanistic view, the CMM satisfies the requirements for an adequate computational model. At the isolated level, the model depicts how the mind processes information. At the constitutive level the model maps information processes onto brain processes. At the contextual level, the CMM is activated in its environment, enacting brain-body processes as information processing mechanisms.

The CMM displays multiple realizability in that the brain-body has several methods for accomplishing a recall task: Long Term Memory can be used; a notebook can be consulted; or an electronic device can be used. All recalls are treated as adequate by the mind. The CMM can be used by philosophers to consider the impact of different methods of realizability by the mind.

Implications to the HEC/HEMC debate were shown using the CMM. The model was used to resolve challenges to HEC past endorsement, processing and parity claims. The model was used to depict broader applications in terms of complementarity and other minds as external memory.

The next chapter will discuss implications and future work for applications of the model.

CHAPTER 6 LIMITATIONS AND FUTURE WORK

6.1 Limitations

The purpose of this section is to make a statement of limitations for the thesis and to lay out future work.

A conceptual model of memory (the CMM) has been presented in the context of a mechanistic account, i.e. an account which coheres to the well-formedness conditions given in Russell's theory of types in which objects of a given type are built exclusively from the objects of preceding types (those lower in the hierarchy), thus preventing loops from which paradoxes emerge (Russell, 1908). Referring to Figure 12 there may be seen a series of levels of types in which objects of a given type are built exclusively from the objects of preceding types (after Calvin, 1997). A mechanistic account comprises three adjacent layers of the levels of explanation. In particular, it may be seen that the mechanistic model at the level indicated by "1" encompasses different Contextual, Conceptual, and Constitutive levels than a mechanistic model at the level indicated by "2". As further indicated in Figure 12, the mechanistic model "2" could be moved up or down the levels of explanation according to the explanatory level of interest. In the case of the CMM the mechanistic model is directed to the highest levels of explanation of Figure 12, corresponding to the mechanistic model "1".

In terms of Milkowski's descriptives, the CMM is an object formed of entities at the isolated or philosophical conceptual level, with a super-ordinate Contextual level and a sub-ordinate Constitutive level. The mechanistic account allows for the assignment of entities to appropriate levels so that arguments based upon boundary crossing errors may be resolved.

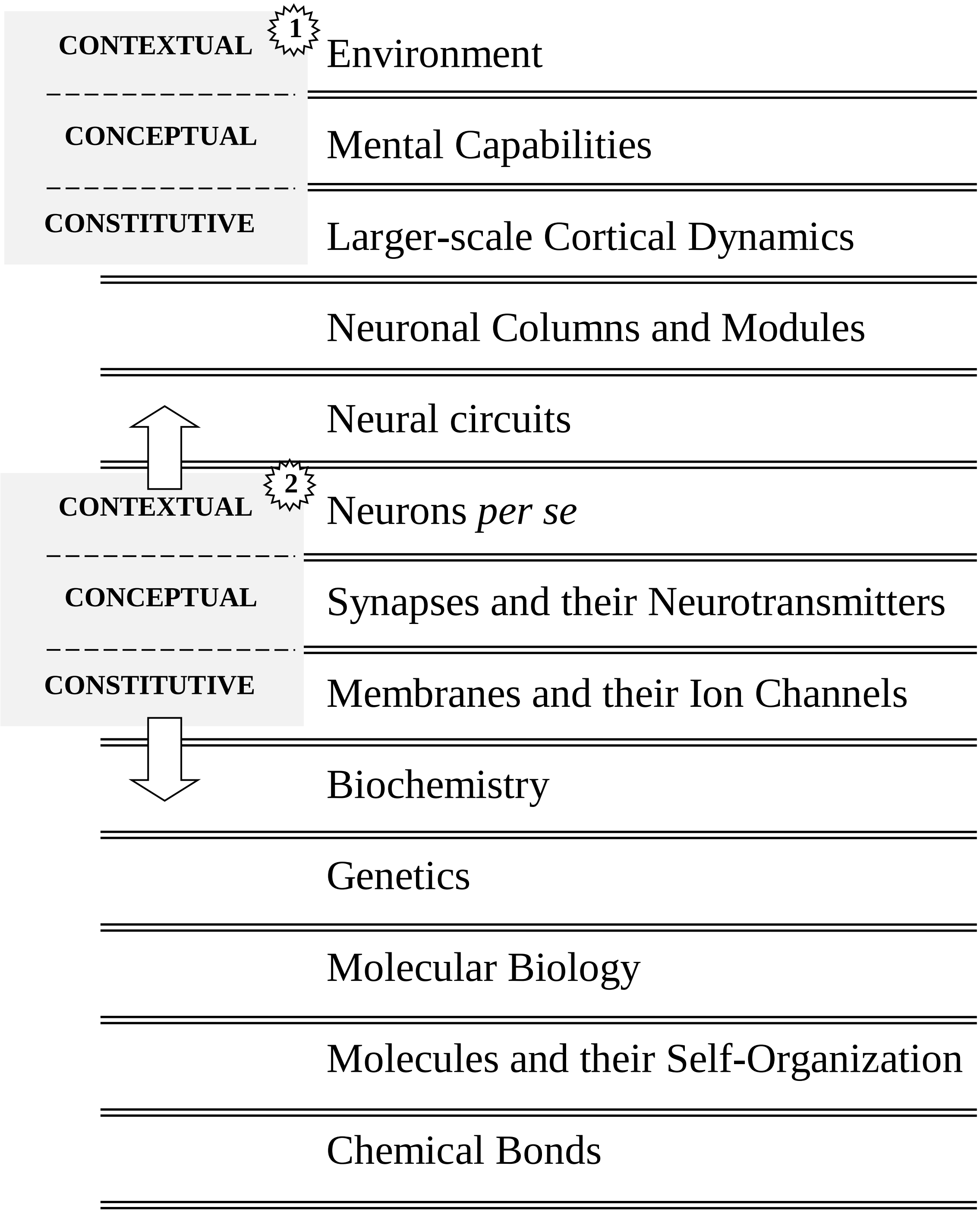


Figure 12 – Levels of Explanation

With respect to limitations, my project addresses Extended Mind arguments and major objections, a mechanistic account of computational modelling, and an exposition of the Extended

Mind claims by way of a computational model of memory (CMM). The CMM is a model that is limited to memory as a specific kind of cognitive process. It does not speak further to overall cognition, for instance, emotions, judgement, reasoning, semantic processing or the producing of language. The CMM carves out part of the brain's functionality, and is poised to become part of a larger schema if one is developed. The model is restricted to conceptual processes that could be realized in brain mechanisms or functionally equivalent substitutes.

The CMM is a tool that can be used to show the conceptual boundaries for the philosophical arguments such as Extended Mind. The key element of the model is the C/I which provides a screening for salience for which the insula brain region is a key participant. The recursive nature of the search through the stages of memory as depicted by the model shows how the processing done by the mind in establishing what it is its own, is facilitated by way of the information processing loop the mind follows in its continuing search for cues (either internal or external) until a decision regarding ownership may be reached.

Possible objections to the model are that it restricts memory to information. I would answer this objection in the following manner. First, the model is a conceptual account of the way in which the mind stores and processes information. Second, as a computational model, by its very nature, it deals with memory as information processing. Finally, under the mechanistic account, the model is situated within a contextual environment and is constitutively realized by way of brain mechanisms. As shown in Figure 12, the three-layered approach can be used as a sliding scale down to finer levels of granularity wherein the conceptual layer becomes the contextual layer for the next level down or alternatively the constitutive layer for the previous level above and so on. When used in this manner, the mechanistic account operates to facilitate keeping the parameters of conceptual, contextual and constitutive layers clear and separate for each level of explanation.

The dataset for the thesis was built and bound upon three main areas of philosophical research, which are, extended mind hypothesis, philosophy of memory and computational modelling. The dataset includes major arguments for and against the extended mind hypothesis as well as those relating to the second wave arguments for complementarity. I used Clark and Chalmers' seminal paper, "The Extended Mind Hypothesis" (1998) as a starting point and followed its sources and citations. I also considered more recent publications by those authors, including Clark and Chalmers, in order to maintain an in-depth understanding of the developing arguments, challenges and retorts involved in the debate. Included here are Frederick Adams and Kenneth Aizawa, Robert Rupert, Mark Sprevak, Michael Wheeler and Mark Rowlands.

Sources from the philosophy of memory include those that recognize and argue for and against external memory possibilities. John Sutton and Richard Menary figure prominently in this area.

Computational modelling sources consist of those that are representative of the historical types of computational modelling of the mind. These include Jerry Fodor, Herbert Simon and Allen Newell, David Marr, and David Rumelhart, Geoffrey Hinton and James L. McClelland. Some sources were used as a result my attending the 2013 Philosophy and Theory of Artificial Intelligence conference, where an early iteration of the CMM was vetted and I encountered the latest research in Philosophy and AI. These sources include Aaron Sloman who added a mainframe view to computational modelling and Marcin Milkowski whose mechanistic schema can be used to test computational models.

Other sources include those in psychology and neuroscience that serve to support the brain mechanisms involved in the constitutive level of the CMM. Memory researchers include Alan Baddeley and Graham Hitch, and K. Anders Ericsson and Walter Kintsch. The dataset for future work links to the claims of the CMM, the thesis statement as to the benefits or detriments of extended human memory and possibilities for computer and human memory interaction in general.

In this section I have demonstrated that the limitations for the thesis and the CMM as operating at the isolated philosophical conceptual level with the environment as a contextual layer and examples of multiple-realizable mechanisms at the constitutive level.

6.2 Future work

The purpose of this section of this chapter is to examine future work for the CMM. With a focus on the individual, future work comes in the form of the effects of external influence on memory content, and therapeutic methodologies. On a wider scope, the CMM is useful in modelling the impact of over-reliance on external devices and Internet resources. Finally, the CMM can be instantiated as an example of Artificial Intelligence.

A highlight of the CMM is the C/I mechanism which is situated at the start of the information processing cycle. The CMM in action shows the influence of the salience mechanism on the decision-making process, since it is the C/I mechanism that determines the next steps for dealing with encountered information. As a screen for salience, and possibly constituted by the insula brain region, the C/I is engaged up front in an executive decision-making role to determine the next step in the processing of encountered information. Once assessed, appropriate information is accepted for further processing, while information deemed to be inapplicable can be segregated. Due to the recursive nature of the C/I mechanism, information processing is subject to successive salience checks which can permit the search to continue more deeply using internal mechanisms, or redirect the search to consult external mechanisms at any stage in the process. C/I efficiency is a factor in whether processing is internal or external. External mechanisms can be consulted for convenience as more direct and faster lookups, or they can be used to complement internal memory. A more efficient C/I means that I can quickly recognize my own content and determine the relevance of new information to my current knowledgebase. The C/I's recursive processing means that the amount and quality of the information we store and use will in turn be reflected in the decisions we make.

The ability to cross reference information and draw on our experiences to make predictions based on past experience is one way we learn. Practising this ability means continually incorporating new information, cross referencing it with what we already know and then filing our newly learned experiences into Long Term Memory (LTM), functionally making us smarter. The less we catalogue, the less we have to work with, and the less we have to work with, the less we can associate to or build on. What this means is that without pertinent content in LTM we are operating solely on what we have in STM, a dynamically-sized buffer of short term memory, whose size depends on how much and how well it is used. The CMM can be used to model research by E. Arnau, S. Ayala, and T. Sturm (2014) who suggest that the capability to make judgements, and the strength and quality of judgements, is strengthened by past experience of doing so. They explain how people make judgements and decisions in everyday life under time and information-limited constraints (Arnau et al. 2014, 50).

Research by B. Zhu, C. Chen, E. F. Loftus, C. Lin, Q. He, C. Chen, H. Li, G. Xue, Z. Lu and Q. Dong (2010) suggests there is a link between overall intelligence and susceptibility to misinformation. They found a significant correlation between memory, including working memory capacity, and false memory creation with misinformation. Zhu et al. suggest that higher intelligence can provide increased immunity against false memory creation. They explain, “individual differences in misinformation or false memory were significantly related to measures of intelligence, perception, memory, and face judgement...Our results showed that intelligence was significantly related to misinformation false memory…People with higher intelligence scores were less likely to incorporate post-event misinformation into their memory of the original event.” (Zhu et al., 2010, 552). The CMM can be used to show the implications of the link between shallow internal processing and C/I efficiency, which could correspond to Zhu et al.’s research into the correlation between intelligence and the ability to distinguish false information.

6.3 Reframing

The CMM can depict the relationship between the capability to discern and the susceptibility to memory reframing. The C/I is the first step in processing encountered information and is responsible for decision-making with respect to the next steps to be taken. A C/I could become weak due to over-reliance on convenient external references at the expense of exercising internal mechanisms. An inefficient C/I might not adequately screen for detail and accept false information as its own. One area of vulnerability of the C/I is the influence of others on our memories. As depicted by the CMM, other minds can be sources of external memory (see Figures 9, 10 and 11).

Research by S. J. Frenda, L. Patihis, E. F. Loftus, H. C. Lewis, and K. M. Fenn (2014) indicates that there are longer term effects of exposing personal memories to external influences, which is evident in the fragility of the creation and recall processes in terms of susceptibility to tampering and corruption. Discussing the correlation of sleep deprivation with increased susceptibility to false memories, Frenda et al. suggest the importance of non-interference and alertness during encoding. They explain how memories are not recorded in a storehouse in the brain, but are constructed using information from multiple sources. Furthermore, memories can change by way of suggestive influences or post-event information (Frenda et al., 2014, 1). They suggest a key insight from studying false memories is that memory-distortion results from various phenomena and is not limited to just one process (Frenda et al., 2014, 7). Frenda et al.'s research can be modelled using the CMM. Their explanation of memory being constructed from different sources can be shown by way of the CMM's internal mechanisms, as well as the various forms of external resources. Furthermore, the fragility during memory creation and recall can be shown by the depth of processing involved at different stages of the model in action.

6.3.1 Transactive and Group Influence

Research by William Hirst and Gerald Echterhoff found that in certain social interactions, people do not remember all of what they are capable of remembering in ordinary conversations (2012, 62). While the benefits of collaborative remembering include transactive memory and collaborative facilitation, the costs come in the form of collaborative inhibition, information sample biases and audience tuning. The following points summarize the effect of conversational remembering on subsequent memory:

- conversational remembering is always selective
- one participant can influence others in various ways
- the effects must be understood in social terms
- social influences are difficult to eliminate
- these influences affect both speakers and listeners

- for speakers to reshape their own memories, they need to create a shared reality with the listener

  (Hirst and Echterhoff 2012, 74).

The CMM can be used to depict these effects by way of modelling transactive and collaborative memory (see Figures 10 and 11). In these cases, the model shows how deeper learning in the individual might not be fully exercised when engaged in group memory activities. Since memory is shared amongst the group and group members serve as external memory for each other, the strength of the salience mechanism plays a role in the how or how much external factors influence internal memory. Research done by Charles B. Stone, Amanda Barnier, John Sutton and William Hirst (2012) shows how this sort of external influence not only affects group memory, but any memory that is socially shared with a group. The CMM depicts this as individuals sharing the same external memory (see Figures 4, 5 and 11). Stone et al. draw a relation between socially shared memories and forgetting of autobiographical memories, serving to exemplify the volatility of even our most personal and precious memories. Outlining the effects of Retrieval Induced Forgetting (RIF) on autobiographical memory, their findings provide insight into the way in which autobiographical memories and in turn, personal identity, can be shaped by social influences. They state, “Researchers have understood for some time the connection between autobiographical memory and personal identity as well as the extent to which the self is socially constructed” (Stone et al., 2012, 14). Examining RIF in the course of conversation, Stone et al. found that in cases where the conversation consisted of selective retrieval of memories, forgetting was induced in both the speaker and the listener, a process that unexpectedly influenced autobiographical memories. Furthermore, the RIF travels socially since “the memory recalled by the speaker is also retrieved by the listener”, and RIF “is not mediated by role, ownership or emotional valence” (Stone et al., 2012, 12).

6.3.2 Other External Influences

Noted for the "navy ship cognition" example (1995), E. Hutchins' (2013) offers an elaborated description of "distributed cognition". He explains that "distributed cognition begins with the assumption that all instances of cognition *can be seen* as emerging from distributed processes" (2013, 36, italics his). In this way, Hutchins argues, distributed cognition is not a type of, but a perspective on cognition. Since cognition is seen as an emergent process where groups are gathered and interact as a system, then any cognitive process can be seen as distributed (Hutchins, 2013, 36). He continues, that if there is cognition, then it is possible to investigate how the cognitive process emerges from elements in some system. Hutchins cautions that his view is not a claim about the nature of the world, but a way of looking at it. Hutchins' view of distributed cognition is that it is dynamic and variable, with no fixed boundaries. The CMM has been used to depict distributed cognition. Further mechanistic accounts of the CMM's mechanisms might be useful in demonstrating Hutchins' later proposal to investigate how the cognitive processes emerge from elements in a system.

Taking a wider view than distributed cognitive systems, Kim Sterelny (2010), in "Minds: extended or scaffolded", argues for a more general phenomenon of organism and environment scaffolding. Sterelny's claim is that we engage more with our environment than just cognitive extension; organism and environment are scaffolded to include language, niche construction and other historical environment adaptations, which have cross-generational effects (2010, 480). Sterelny states that there is evidence of scaffolding in cultural practices, as with parents' ideas and actions transferring to the child. There is more than just the mind and mental world extension; all of body and environment are an extension as well. Sterelny argues that extended cognition theory is plausible with single-user resources, but there is no need to privilege that small space; “extended mind cases are special cases of a general phenomenon” (2010, 480). Furthermore, Sterelny emphasizes “the role of active agency in enhancing the adaptive fit between agent and world” (2010, 465). The CMM demonstrates extended cognition, (see Figures 4-11, Chapter 5), and the multiple realizability of the mechanistic view would be useful for Sterelny to apply extension to other phenomenon he describes.

In “The Socially Extended Mind”, Shaun Gallagher (2013), explores a liberal socially extensive view of extended mind, a view that involves enactive, rather than functional relations. He explains that social interactions not only include other people, but also involve “institutional structures, norms and practices”. Gallagher proposes the need for a “critical theory” approach to examine which for instance, institutional, social and cultural practices constitute extended mind because of the influence these practices have on us. He elaborates, “Decision making is really a matter of embodied, emotion-rich, environmentally modulated processes”, even though behavioural outward appearance suggests one is engaged in inner mental processes (Gallagher, 2013, 11). Although individuals make the decisions, their surroundings provide an important contribution regarding the choices that are made. Gallagher suggests that extended mind theory “offers a new perspective for understanding decision making, judging, problem solving, communicative practices and so forth”, spilling over into larger contexts of social, legal and political arenas (2013, 12). Gallagher’s ideas and theory can be modelled using the CMM as a basis and then adding multiple external sources, (see Figures 9-11, Chapter 5), each with different degrees of salience, to be included in the decision-making process.

6.3.3 Therapeutic Applications

That memories are susceptible to reframing by external influences can be favourable from a therapeutic perspective. Research into the effects of memory exposure to external influences shows how memories can be altered, even autobiographical ones. As shown by the CMM memory can be stored internally or externally and regardless of location, information in memory is subjected to a screen for salience (see Figure 5). In a therapeutic sense, this opens the door to talk therapy as a way of positively dealing with negative emotions associated with bad memories. Lou Marinoff explains one such method, philosophical counselling, which is intended for clients who are rational, functional, and not mentally ill, but who can benefit from philosophical assistance in resolving or managing problems associated with normal life experience. Clients seek help with problems related to issues of private morality or professional ethics, meaning, value, purpose, personal or professional fulfillment, underdetermined or inconsistent belief systems or and other issues requiring philosophical interpretation of changing circumstances (Marinoff, 2002, 252). Philosophical counselling is a method by which informed decision-making and misinformation-spotting factor into the ability to discern the validity of encountered information. In the counselling process the client relates a problem and the philosopher initiates a dialogue with the client that involves deeper questioning as to the nature of the client's beliefs regarding the specific problem area. The client learns how to recognize inconsistencies in their own thought processes by thinking more deeply and exhaustively about their own views and beliefs regarding a particular subject matter. Group counselling involves each person giving their views and examples of a specific concept and the group democratically selecting the one that agree most accurately represents the concept. The person whose view is chosen is then asked to recount and discuss their view with the rest of the group as well as answering any questions the rest of the group might have. The benefit of this methodology is that beliefs can extracted under the guidance of a trained philosopher who in turn educates the client in how to identify areas of inconsistency within their own ideas. The CMM can model this process in that the philosopher as an external resource can offer depth of a particular area of expertise and a strong degree of salience, which is demonstrated by the philosopher and learned by the client at a deep level of understanding. The key to the success of philosophical counselling is that the philosopher engages with the client at deeper levels of processing so that underlying belief systems can be analysed and adjusted as necessary in order to solve the client's particular problem.

Philosophical counselling works by educating clients with respect to decision-making processes by way of showing the individual how reason and emotion factor into the choices we make and the problems we face. A client can be counselled on how to research further information prior to making a decision, and more importantly how to assess the personal relevance of the information. For example, a client suffering from post-traumatic stress can be educated in the value of externalizing the memory by either writing it out to external storage, talking to a counsellor, or both. The CMM shows how externalizing memories can free up the mind for other processing. It also shows how shared memory can be influenced by other group members. The benefit of sharing with a trained philosophical counsellor is that the counsellor can help the client to issue-spot any areas of dissonance in the client's beliefs and behaviour. For example, a client who is dealing with negative memories of having had an abortion might be consciously unaware of being conflicted about the teachings of her Catholic upbringing and the church's views on the right to life.

Another therapeutic way of dealing with bad memories is to alter the way that they are recalled so that the memory can observed from an outsider perspective instead of having to be relived with each recount. G. Nigro and U. Neisser (1983) explain the effect of recall circumstances and context on the resulting perspective of autobiographical memory recall. They found that memories are reconstructed and the “point of view” can be altered during recollection. Longer intervals between original events and recall result in a higher degree of observer or third person perspective memories. Greater emotional significance influences toward a personal point of view remembering. Autobiographical memories are categorized as either, field memories, which are those recalled from a first-person point of view, and observer memories, which are recalled from a third-person perspective. Nigro and Neisser explore the relation between field and observer memories, showing the meaningfulness of this phenomenal distinction as related to characteristics of the original experience, the purpose of the recall, and the interval between the event and the recall (1983, 467). Regarding characteristics of the original experience, Nigro and Neisser explain that although observer memories do occur, and are often produced by a process of reconstruction in memory, they can occur on their own. High degrees of emotional self-awareness are often experienced as observer perspective (1983, 481). Furthermore, they found that personal significance of situations plays a role in the extent to which emotion and self-awareness are evoked, as well as how much the memory is reworked. Individuals differ in degrees of emotion experienced in similar circumstances, as well as the purpose of their recall. For instance, a poet, a painter and a building developer see a landscape much differently, and recall with varying levels of emotion. The poet recalls in order to recount the emotional significance of the scene, the painter remembers the presentation of the scene, while the building developer assesses potential income of multi-unit dwellings (Nigro and Neisser, 1983, 482).

The purpose of the recall also affects the perspective of the memory. Deliberate attempts to remember the objective circumstances of an event lead to more observer memories, while a focus on feeling, as with the poet recalling the landscape, leads to more field memories. Without specific recall instructions, the default is that individuals remember based on their own feelings

(Nigro and Neisser, 1983, 467). With respect to the interval between the event and recall, Nigro and Neisser found that recent memories tend to be in field mode.

The CMM can be used to model processing sequences that can be used to overcome memory impairments during memory formation. The model shows how external resources can be consulted at any time during the processing sequence. Nathan Cashdollar, Nilli Lavie and Emrah Duzel's (2013) research shows how certain memory impairments can be alleviated when subjects were distracted by non-related information. While the general assumption of distraction during the memory formation process is negative, Cashdollar et al. found that there were beneficial effects of distraction in both damaged, and low memory performance healthy adults. They explain that memories are vulnerable to negative effects of distraction during short term visual memory retention, especially if the distraction scene is categorically related to the object of the memory (2013, 19012). However, when the distraction scene is unrelated, they witnessed an improvement in patients who are "typically impaired when short term memory load is high", suggesting that familiarity has a low level resilience to distraction (Cashdollar et al., 2013, 19022).

6.4 Technology and Memory

A computational model such as the CMM allows a follow-up to Clowes' (2013) recommendation that, due to the pervasiveness of E-Memory, the focus going forward should be to investigate and determine "sensible bounds" of mind-technology integration. We recall Clowes' argument that with respect to cognitive diminishment, HEC has more options and is more interesting in terms of unity and organismic integrity (2013, 131). On the other hand, due to the nature of HEMC's focus on the preservation of the internal and suspicion and resistance towards the external, Clowes claims that HEMC offers more in the way of ethical terms of external interference. While he sees the HEMC theorists' argument as suggesting that if our minds *bleed out* into environmental resources we are diminished in the process, he ultimately suggests that this sort of diminishment is no more a concern than is the use of a calculator as a supplemental tool when doing mathematics (2013, 127-128).

On a positive note, use of external reminders and calendars can help to increase personal efficiency and time management. This is depicted by the CMM as it consults external memory for convenience. In an editorial for *Memory Studies*, Amanda Barnier discusses the importance of her iPhone as "compensating for impairments in [her] current capacity to 'process and use information'" (2010, 293). Barnier points out that she relies heavily on her iPhone to keep track of appointments and for access to the Internet. For Barnier, her iPhone is more than just repository of things to remember, she makes use of calendar reminders and apps to help stay organized in a busy life, as is typical of connected users.

The CMM can show how internal and external memory can be used in a complementary fashion to optimize efficiency and increase intelligence. In "Saving-Enhanced Memory: The Benefits of Saving on the Learning and Remembering of New Information", Benjamin C. Storm and Sean M. Stone (2014) research the effects of the practice of storing information on computers, having only to remember the location versus the content. They conclude that this practice is a benefit to memory for the following reasons: the mind is freed up to start fresh on a second file; there is a change in context when switching between files; and the practice creates an augmented event boundary between the two files (Storm and Stone, 2014, 487). The first benefit demonstrates the substantive and functional benefits of external storage, freeing up the mind for other work. Storm and Stone claim that the ability to offload memory by saving it to files could affect one’s capacity to learn and remember, as well as impact the capacity to think, solve problems and form new ideas (2014, 88). Trying to remember the information without saving it can potentially impede learning of other information, for example, memorizing a grocery list can occupy your mind (2013, 488). Storm and Stone suggest there can be positive effects on learning as a result of being able to save documents. Cognition is frequently and substantially constrained by the accessibility of irrelevant and extraneous information” (2014, 488). They further advocate the benefits of effective use of saving information, such as overcoming constraints of having to remember too much “trivial” information and having to think while holding onto such thoughts.

The CMM can be used to show how over-reliance on external searches negatively affects the ability to cross-reference information and to project the entailments of our decisions. For example, one could be able to locate all of the “how-to” manuals on the Internet, yet be unsure as to what to do with them. Eventually we become a directory look-up, trusting content that’s “out there”, vulnerable to content authors and automatons. We risk becoming programmable or programmed by our own apps. In “Google effects on memory: Cognitive consequences of having information at our fingertips”, B. Sparrow, J. Liu and D. Wegner (2011) argue that when faced with difficult questions, we think of the computer as a *where* rather than the answer to the *what*. In addition, the expectations of computer availability access result in lower rates of recall of the information and enhanced recall of location. From a negative perspective, this practice of remembering location versus content flattens the depth of our knowledge; from a positive outlook, we free up our internal memory capacity for deeper thinking. Comparing this practice to transactive memory, Sparrow, Liu and Wegner claim, “The Internet has become a primary form of external or transactive memory, where information is stored collectively outside ourselves” (2011, 776). A classic example of transactive memory is the actors in a play cueing off each other's lines, together forming a full dialogue but each having learned only her own part. Properly functioning transactive memory requires access to the contributions of each group member. Sparrow, Liu and Wegner provide a comparison of transactive memory processes of human-computer as external memory, with those that underlie social information-sharing: information is shared easily (both with others and with computers as stores of memory); people tend to forget things they think will be available externally and remember ones that won't be available; and people will tend to remember where rather than what is stored (2011, 778). They conclude, "The experience of losing our Internet connection becomes more and more like losing a friend. We must remain plugged in to know what Google knows" (Sparrow, Liu and Wegner, 2011, 778).

The CMM can be helpful in researching a relation between the amount and types of technology in the classroom and the quality of learning. In "Thinking Beyond the Brain: Educating and Building, From the Standpoint of Extended Cognition in Computational Culture", Michael Wheeler (2011) puts forth concerns about how these technologies are exploited. He uses the example of how students have become accustomed to spellcheck and calculators, and how these have become allowable tools in learning environments (2011, 3). With enabled devices, the problem is, for one, how to educate, and furthermore how to test for intelligence going forward. He raises the question of whether a boundary be drawn to limit how much technology is allowed in the classroom, and if so, what type of technology and how much (Wheeler, 2011, 7).

In "Towards a Philosophy of the Web: Representation, Enaction, Collective Intelligence", H. Halpin, A. Clark and M. Wheeler (2010) examine a philosophy of the web, prescribing philosophy of cognitive science and mind as the best possible underlying fields within which to approach this debate. Referring to what is "sometimes called 4E (embodied, embedded, enactive, extended) cognition", they claim this area is rich for philosophical debate, one in which the examination of human-web interactions could yield clues into other philosophical issues (Halpin, Clark and Wheeler, 2010, 1). These issues arise in the form of representation, meaning and cognitive credit. First, representation in the web, *the semantic web*, could benefit the classical Artificial Intelligence frame problem, in for example determining mechanistically which items of the vast amount of information are relevant, and how they are updated within and across changing activity. Second, enactive searches using social networking and collaborative tagging, and statistics driven by Google's search engine contribute to the idea of "meaning is use" (2010, 2). Halpin, Clark and Wheeler note that while enaction typically refers to a biological person, the web side deserves research consideration (2010, 3). Third, regarding cognitive extension and collective intelligence comes the issue of who gets cognitive credit if, for instance, we all simultaneously update a Google map (Halpin, Clark and Wheeler, 2010, 4).

6.5 Artificial Intelligence

The CMM is a schema of mechanisms as intermediate functions around memory recall that are present in human agents, and required in non-human agents to be recognized as intelligent. That the CMM conforms to an adequate mechanistic view offering three levels of explanation, facilitates the model's instantiation. The isolated layer provides the program that outlines how information is processed and stored as memory. At the constitutive layer these processes are realized in human brain mechanisms. The benefit of multiple realizability was shown in the use of external memory and broader applications of the model involving other minds.

Aspects of the model could also be realized by using electronic Ternary Content-Addressable Memory (TCAM). A Content-Addressable Memory (CAM) is a realization in hardware of what is also known as an associative array. Whereas normal computer memory works by returning a data word associated with a supplied address in memory, a CAM is a hardware design in which a data word is supplied and the entire memory is searched to determine if that data word is stored anywhere within the memory. CAM searches take the same amount of time as a single word lookup in normal memory computer memory. If the data word is found, the CAM returns the one or more storage locations where it was located and also returns the associated pieces of data. Original CAM’s used data words consisting of binary 0’s and 1’s, and Ternary CAM’s added a third state, “X”, a “don’t care” state which allows a match on data words having either a binary 0 or 1 in a particular location. This added state vastly expands the associative capabilities to “almost matched” associations. Being able to find the content of the memory addresses around the searched data word allows the search to generate associated cross-referenced content for further searches. These next-generation CAM’s are termed Ternary CAM’s because of the three possible matching states. The capabilities of TCAM’s has resulted in their use in database lookup engines and artificial neural networks. The latter use is application which could realize at least some aspects of the C/I module.

6.6 Summary

In this section I have outlined future work for the CMM in the form of studying possible advantages to the applied realm as well as studying potential disadvantages to the use of different memory media.

SUPPLEMENTAL LIST OF FIGURES

Supplemental Figure 1– Computational Model of Memory

Converter/Interpreter

Scans for obvious logical errors and inconsistencies and salience.

Screening process/function, reaches for more features, if not immediately obvious, on encountered information.

Buffer Pool

Limited Capacity with dynamically sized and operating much like a cache in that once it is full, the newest version of information overlays the oldest.

Cross Reference

Searches associations based on recency of references. Multiple searches yield deeper associations.

Catalogues the information to be retained in Long Term Memory.

Long Term Memory

Depth of search increases with multiple passes.

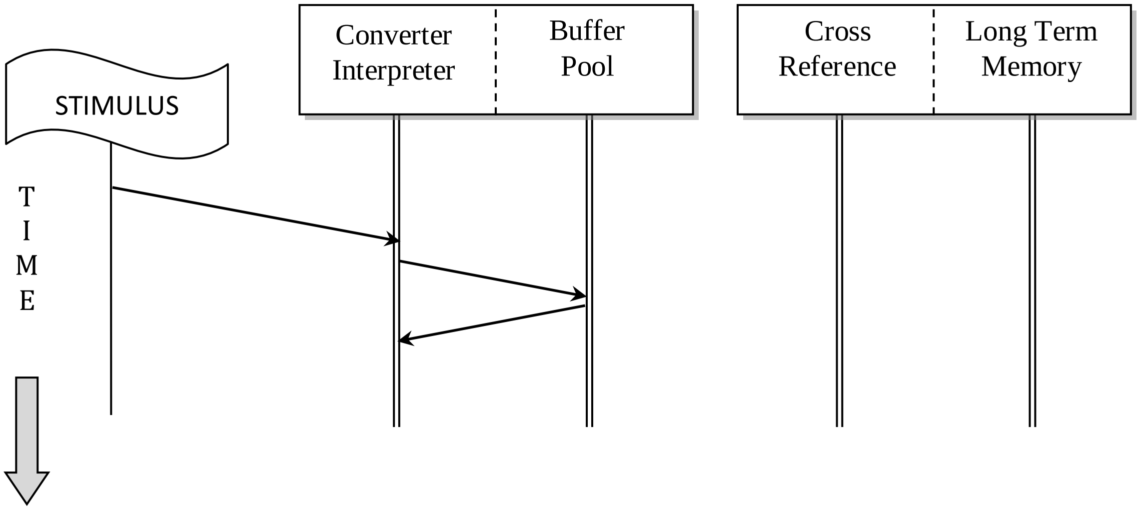
Sequential-like search, newest to oldest, involving time and compare functionality.

External Storage

Information is stored externally, directly accessible for search and retrieval at any stage in the process flow.

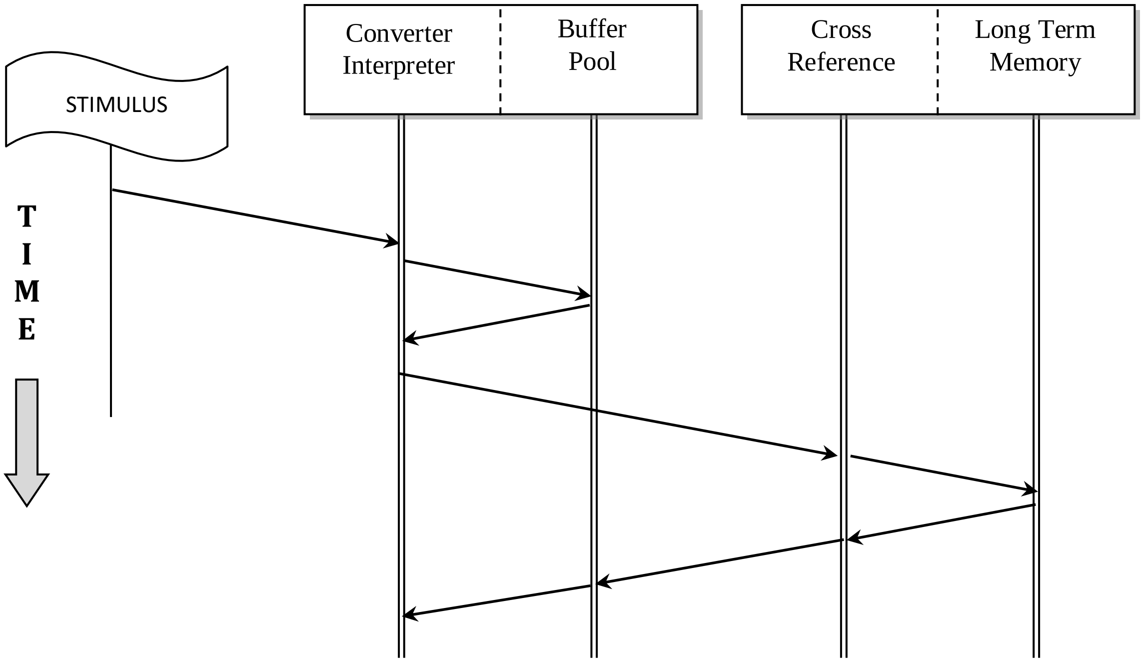
Figure 1 depicts the two sets of paired mechanisms along with the EXTERNAL STORAGE. Later figures depict the model in operation in differing contexts.

Supplemental Figure 2 – Simple Recall from Buffer Pool



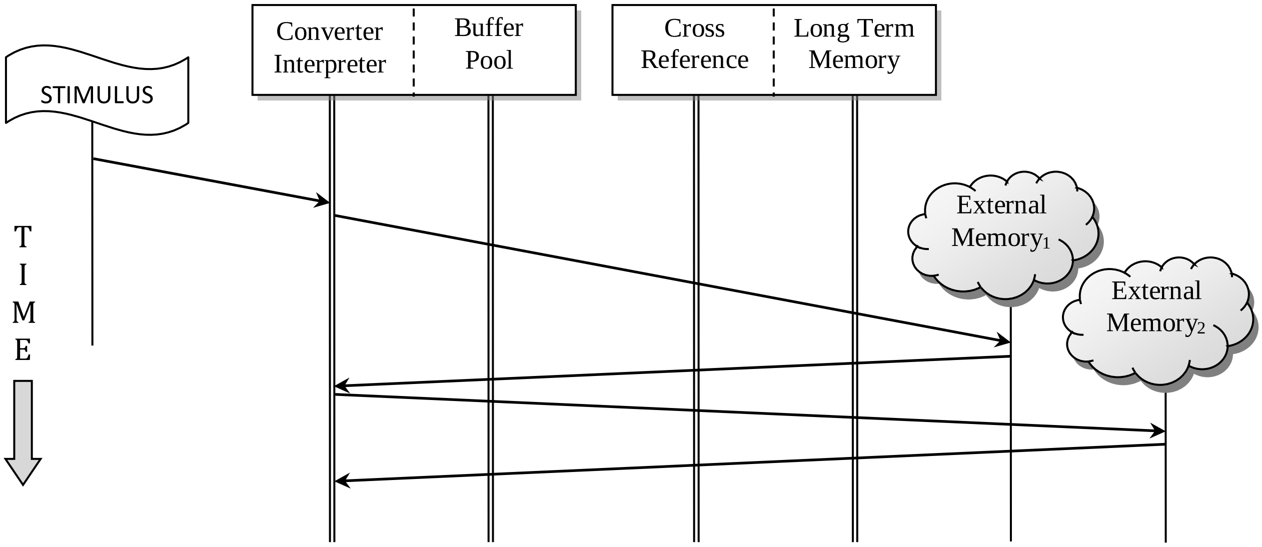
STIMULUS is recognized and made sense of at the CONVERTER/INTERPRETER. Requisite information is sought in the BUFFER POOL and found. The CONVERTER/INTERPRETER can then proceed to take appropriate action based upon that memory.

Supplemental Figure 3 – Recall via Cross Reference and Long Term Memory



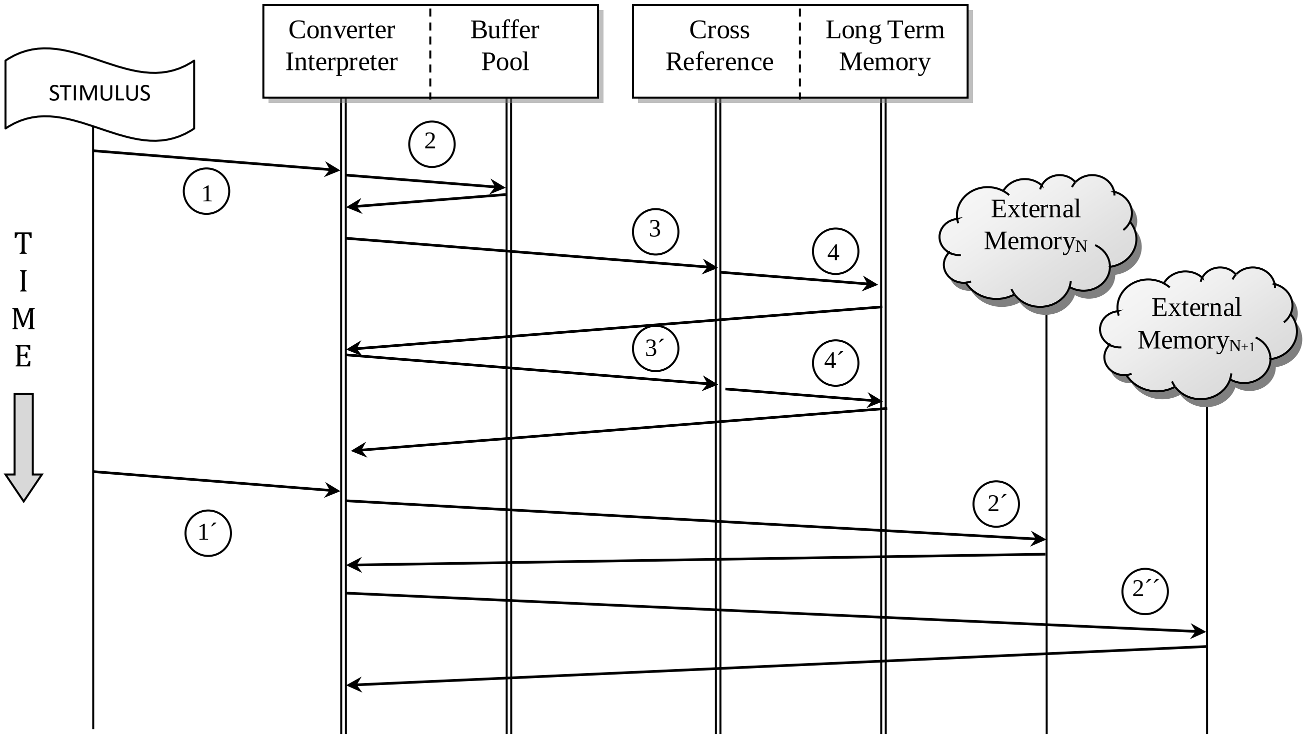
STIMULUS is recognized and made sense of at CONVERTER/INTERPRETER. Requisite information is sought in BUFFER POOL and not found. CONVERTER/INTERPRETER then proceeds to access CROSS REFERENCE module for memories catalogued in LONG TERM MEMORY. Having found a relevant memory, the CONVERTER/INTERPRETER can then proceed to take action based upon that memory.

Supplemental Figure 4 – Recall via External Memory



STIMULUS is recognized and scanned for salience at the CONVERTER/INTERPRETER. Requisite information is sought in EXTERNAL MEMORY$_1$ *and not found. The CONVERTER/INTERPRETER then proceeds to seek requisite information in EXTERNAL MEMORY*$_2$*. Having found a relevant memory, the CONVERTER/INTERPRETER can then proceed to take appropriate action.*

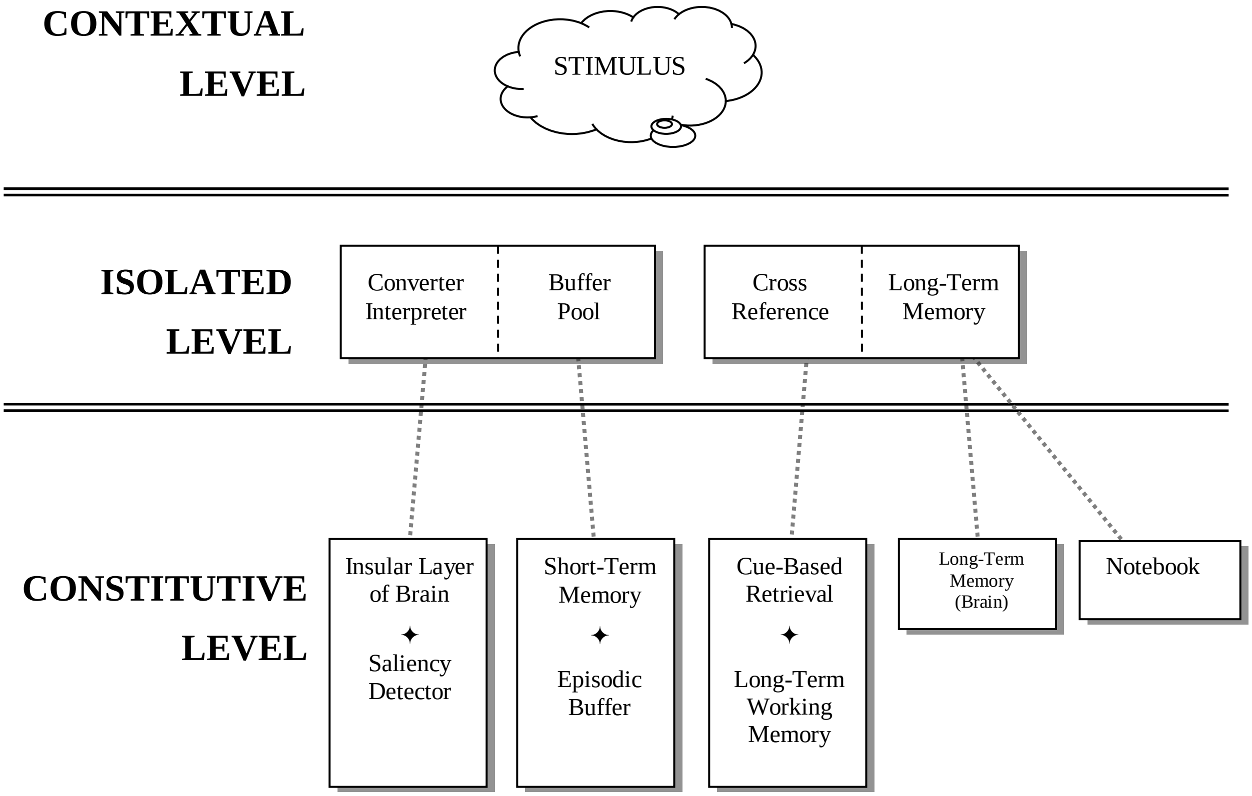
Supplemental Figure 5 – Complex Memory Task



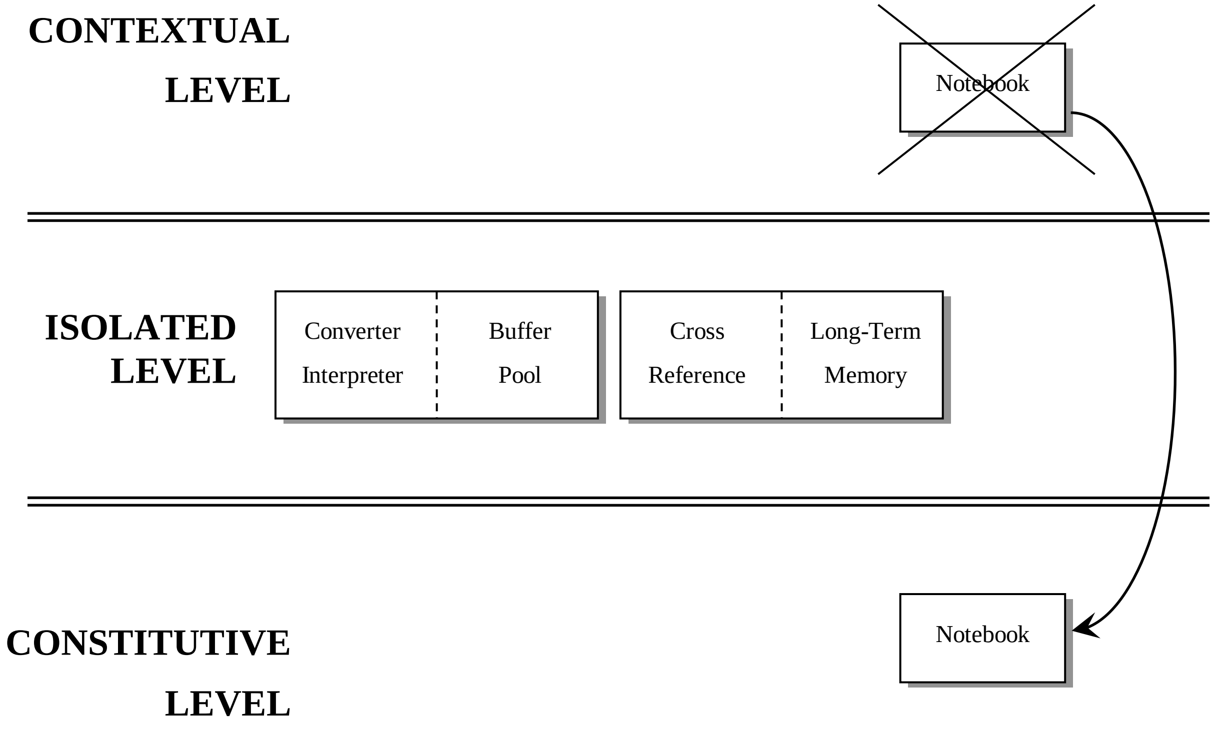
Supplemental Figure 6 – Levels of the Mechanistic Account

CONTEXTUAL LEVEL	Environment
ISOLATED LEVEL	Concepts
CONSTITUTIVE LEVEL	Physical

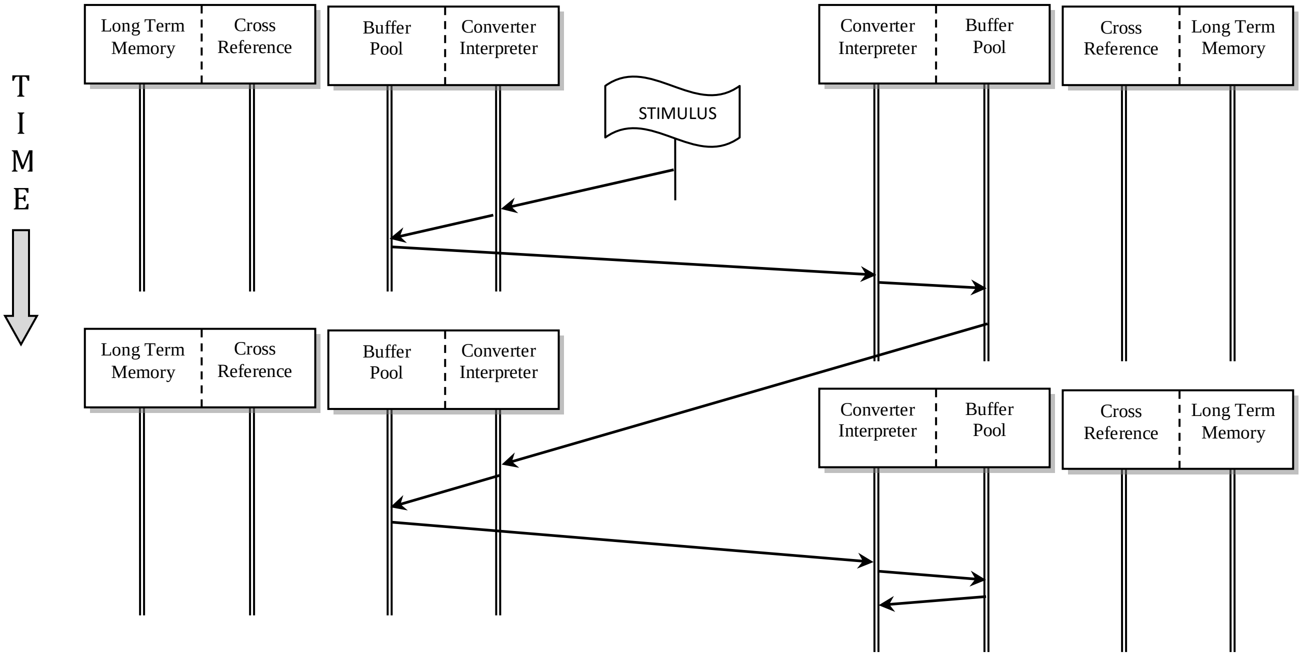
Supplemental Figure 7 – The CMM under the Mechanistic Account



Supplemental Figure 8 – Boundary Confusion and Category Errors

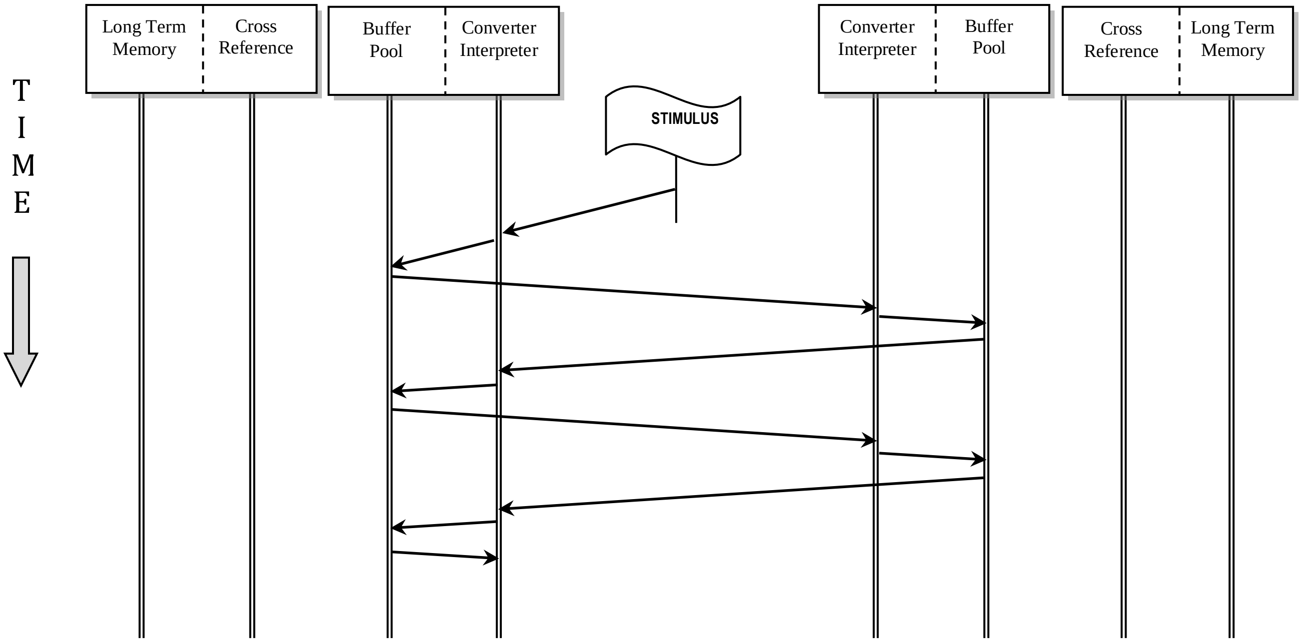


Supplemental Figure 9 – Distributed Memory

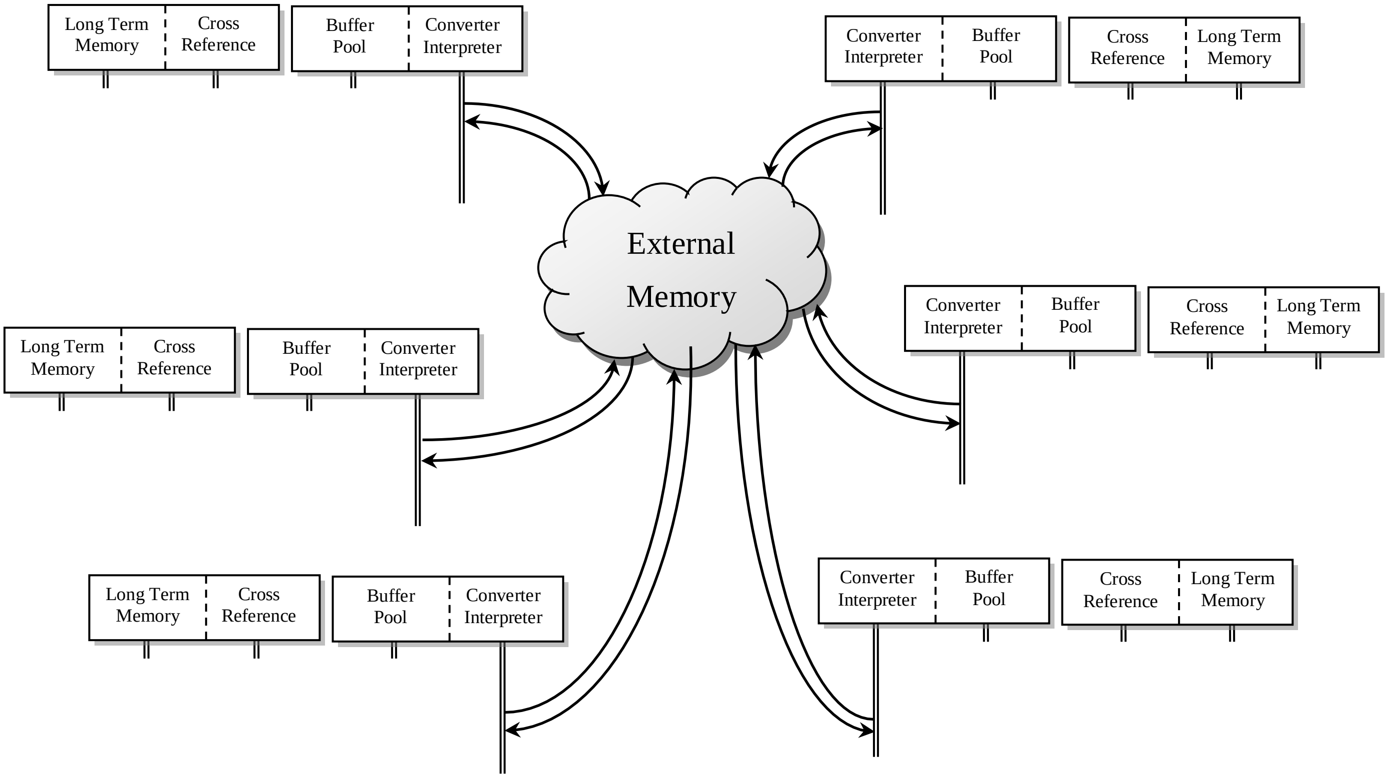


Other minds act as successive cues for each other. The environment in which recall occurs plays an important role.

Supplemental Figure 10 – Transactive Memory

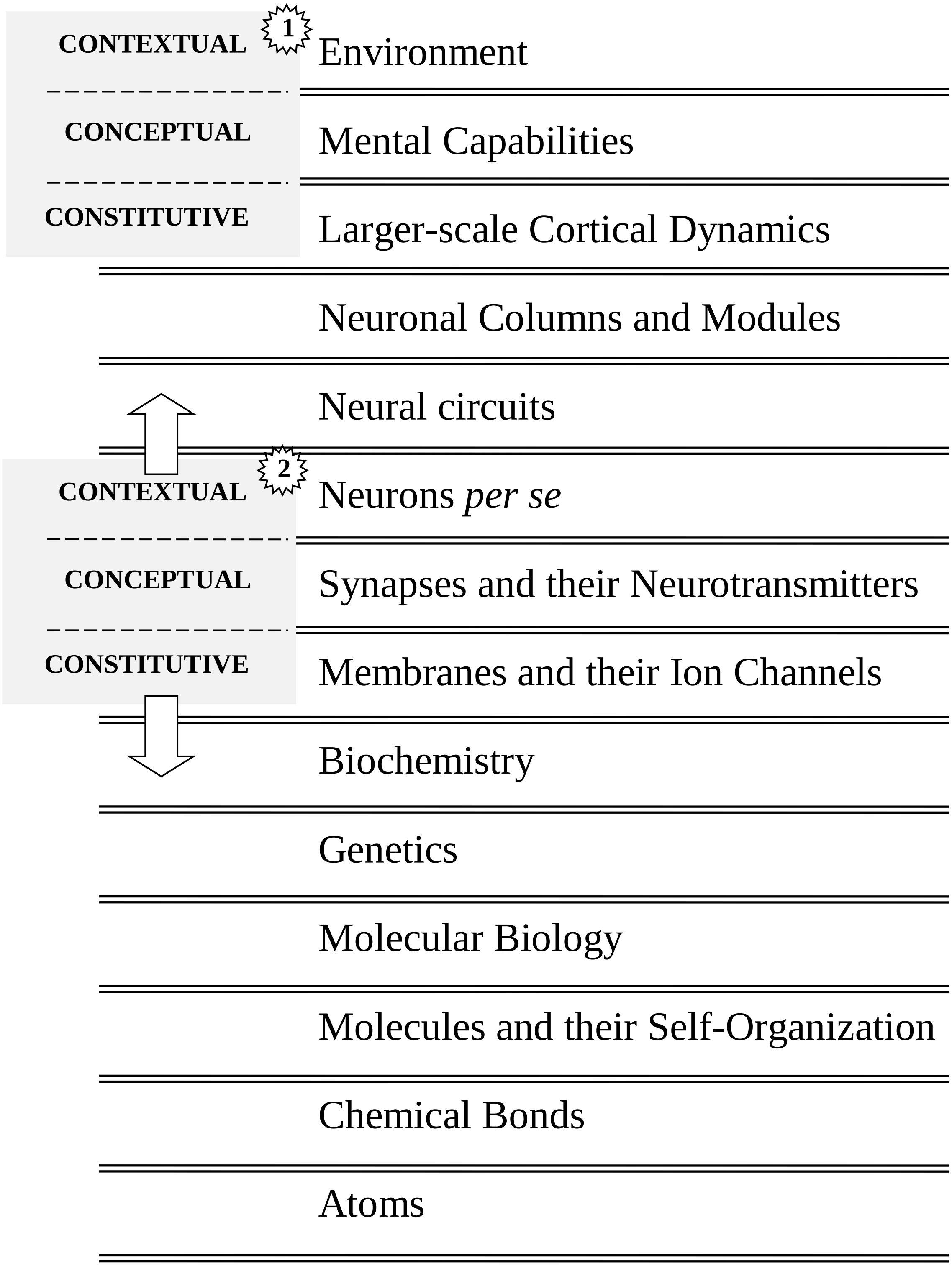


Supplemental Figure 11– Collective External Memory



An EXTERNAL MEMORY is used as a common reference for multiple minds, emphasizing external search while minimizing internal search.

Supplemental Figure 12– Levels of Explanation



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