THE ROLE OF EPISODIC MEMORY IN ARTIFICIAL INTELLIGENCE

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ABSTRACT

THE ROLE OF EPISODIC MEMORY IN ARTIFICIAL INTELLIGENCE

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The aim of this work to is analyze the role of episodic memory in Artificial Intelligence (AI). Memory and Artificial Intelligence are one of the most important issues in philosophy. A thinking machine is the main topic in AI. The relation between episodic memory and AI has been analyzed in terms of high level cognitive capabilities such as perception, learning and reasoning. Episodic memory is essential for not only human intelligence but also AI. Since, episodic memory supports some important high level cognitive capabilities. Here, I argue that if a proper episodic memory model is designed, it is possible to develop AI as human intelligence.

Keywords: Memory, Episodic memory, Artificial Intelligence

ÖZ

OLAYSAL BELLEĞİN YAPAY ZEKA İÇİNDEKİ ROLÜ

Eğilmez, Ebru
Yüksek Lisans, Felsefe Bölümü
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Bu çalışmanın amacı, Yapay Zeka (AI)'da olgusal belleğin rolünü analiz etmektir. Bellek ve Yapay Zeka felsefenin en önemli araştırma alanlarından biridir. Yapay Zeka 'düşünebilne makineler' ile ilgili alandır. Olaysal bellek ve Yapay Zeka arasındaki ilişki algı, öğrenme ve akıl yürütme gibi üst düzey bilişsel yetiler açısından analiz edilmiştir. Olaysal bellek insan zekası için önemli olduğu kadar Yapay Zeka için de önem taşımaktadır. Olgusal bellek bazı önemli üst düzey bilişsel yetileri destekler. Bu nedenle, uygun bir olaysal bellek modeli tasarlanabilir ise, insan zekasına yakın bir Yapay Zeka geliştirmenin mümkün olduğu söylenebilir.

Anahtar Kelimeler: Bellek, Olgusal Bellek, Yapay Zeka

To My Brother and My Mother,

To the soul of My Father

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

Memory is considered as one of the most important aspects of human cognition, because of the fact that it is related to not only storing and remembering the past experiences but also affecting the future events by means of the past experiences. Human beings actually keep various information in their memory so as to survive. For example, the information in the different contexts such as the date of their birthday, their home address, the capital city of the countries, and the boiling temperature of water is stored in memory.

Memory is not a simple system because of the fact that it has different components, which are related to store various information; and these definitions are going to be mentioned in detail in the third chapter. This diversity actually causes different questions, which must be answered, such as how this diversity occurs and how these mentioned information are remembered. Therefore, philosophy is interested in the possibility of diversity in memory and investigates the occurrence of diversity. One of the essential diversity in memory is episodic memory. Tulving describes episodic memory in his book *Elements of Episodic Memory* in 1983 by showing the different aspects of episodic memory that are opposite to semantic memory. Episodic memory comprises personal information rather general information due to the fact that it is related to personal events, memories and situations instead of general knowledge, facts and ideas. In addition, it is only a past-oriented system whereas the other memory systems are not related to past time. That is one of the properties, which makes episodic memory essential since the past has effects on the present and future. As it is defined, episodic memory is encoding, storing and remembering the person's own past experiences and specific events occurring in special time.

> Episodic memory is the type of declarative memory we use to recall/re-experience specific events from our own personal history. 'The experience of episodic memory is explicitly tied in with self-consciousness' (Holland and Smulders 2010: 95).

Therefore, it needs an active subject as a rememberer, an observer or a participant of the experience, i.e., the event depends on experience.

In addition, only episodic memory, which is also a past-oriented memory system, is unique to human beings because it requires self-awareness (consciousne**ss[1])** and personal experiences, so episodic memory has interconnection with auto-noetic consciousness[2] to be able to remember the past and image the future. Auto-noetic consciousness consists in self-awareness (consciousness). This type of consciousness is defined as becoming aware of our own self in the subjectively experienced time. In other words, 'self-consciousness (also self-awareness) is to be consciousness of oneself as the subject of consciousness. (To be distinguished from another use of "self-consciousness" as in 'Teenagers are too self-conscious to be spontaneous.')'(Harnish 2002: 209). Episodic memory provides remembering through auto-noetic awareness owing to the fact that auto-noetic consciousness allows the individual to think about the future and travel through back in subjective time. Episodic memory supports 'mental time travel' by means of auto-noetic consciousness. Mental time travel is to go backward into the individual personal past and to forward into the individuals' future through the subjective time. Consequently, there is a connection between episodic memory, auto-noetic consciousness and mental time travel. In addition to consciousness, introspection is one of the most essential components of self-awareness and actually episodic memory. Self-awareness requires introspection so that the individual is able to be conscious of getting the information about his/her own

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1 **'**Consciousness is a mental state that permits one to have a phenomological awareness of one's experiences' (Markowitch, 2003: 180).

2 'Autonoetic consciousness is based upon a specific human capacity of a self reflective mental state of self-consciousness within time and other contextual dimensions so that the person virtually can re-experience the event' (Vandekerckhove, 2009: 5).

mind. Furthermore, episodic memory is related to remembering the occurring time of the event, where the event happened and what it definitely was. In a sense, the main crucial function of episodic memory is remembering especially personal past experiences. In the light of these mentioned views, episodic memory is different from other memory systems. The distinction between episodic and semantic memory in terms of many aspects, which is the one of the main concerns of the thesis, will be analyzed in the third chapter. Understanding of what episodic memory is necessary to be able to show it as a solution for the other scope of the thesis, Artificial Intelligence (AI).

Episodic memory has the significant role in the human cognition because of supporting various high level cognitive capabilities, such as perception, learning, reasoning, problem solving and decision-making. 'Perception' is related to sensations such as smell and touch, perception occurring in process is supported by episodic memory. Since, the event in the environment can be awarded off by means of this perceptual processing. Therefore, the individual is able to make the connection between the two similar situations. 'Learning' is one of the most significant cognitive abilities supported by episodic memory. Learning new things easily occurs by means of the usage of past experience, therefore; the individual is able to learn certain new states or situations by virtue of episodic memory. 'Reasoning' requires episodic memory on account of the fact that reasoning concerns in the individual's past experiences. Reasoning is related to making predictions about the future actions and giving an account for the past actions. Therefore, it is deniable that episodic memory supports this high level cognitive capability. Finally, 'decision-making' is sustained by episodic memory because the individual can deliberately make decision by using his/her past experiences.

Memory, essentially episodic memory is also one of the most essential components of Artificial Intelligence. Artificial Intelligence is one of the most important controversial and contemporary issues concerned by cognitive science and philosophy. "The history of AI can furthermore be reviewed from different perspectives- humanistic, cognitive, sociological, and philosophical among others" (Ekbia 2010: 201). Philosophy is actually interested in the issue in terms of different aspects such as epistemological, technical and ethical. For example, the ethical aspect is related to whether a machine can be moral or not. There are two perspectives related to the occurrence of Artificial Intelligence. The first one is whether a machine is able to imitate what the human mind does. In other words, it is related to whether a machine is able to do what human does. For instance, can a machine be good at solving problems? The second perspective bases on 'thinking machines'. Thinking machine means to give an answer to whether a machine can think as human beings or not.

The famous figure as thinking machine is the Turing Test. It is known as imitation game[3]. The game or test is to be able to 'think'. Turing said in his famous paper '*Computing Machinery and Intelligence'*:

> I propose to consider the question 'Can machines think?' This should be begging with the definitions of the meaning of the terms 'machine' and 'think'… I shall replace to the question by another, which is closely related to it and is expressed in relatively unambiguous (Turing 1950: 433).

The aim of Artificial Intelligence is definitely to understand the human mind and the nature of human intelligence. AI takes a place in different areas such as education, financial forecasting, data mining, Semantic Web[4] and so on. During

[3]The new form of the problem can be described in terms of a game which we call the "imitation game." It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The integrator stays in a room apart from the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. He knows them by labels X and Y, and at the end of the game he says either "X is A and Y is B and Y is A." (Turing 1950: 433)

[4] "The original *Scientific American*article on the Semantic Web appeared in 2001. It described the evolution of a web that consisted largerly of documents for humans to read to one that included data and information for computers to manipulate. The Semantic Web is a Web of actionable information-information derived from data through a semantic theory for interpreting the sysmbols. The semantic theory provides an account of 'meaning' in which the logical connection of terms establishes interoperabilitiy between systems" (Shadbolt, Hall and Lee, 2006: 96).

time, various necessities are required to be able to give a proper answer to the question whether a machine can think or not.

Memory has an essential role in order to give a proper answer to this question. Memory, especially episodic memory, is a witness to all necessary conditions for AI such as consciousness and problem solving. When the memory system in human cognition is well understood, the main problems in AI can be solved. Memory is not a cause for another problem for AI, but instead an encompassing solution. An artificial intelligent system needs to use its own past experience to properly act from its present time through its future time as humans do. In the early period of AI, the memory of the computer system was only used to store the information. The role of memory in Artificial Intelligence has changed due to the novel requirements in order to develop high level cognitive skills in AI, and to be conscious. Therefore, the memory has been developed to increase the high level cognitive capabilities of these systems due to the fact that Artificial Intelligence bases on human cognition. In addition, these systems are designed in accordance with human cognitive abilities so that they are able to advance in the high level cognitive capabilities such as learning, reasoning, sensing, problem-solving and so on. However, these cognitive abilities cannot be easily implemented into the cognitive systems due to the fact that the implementation of episodic memory is harder than the implementation of other memory systems into the algorithmic systems. Seeing that, algorithmic systems are input-output systems. The input-output systems work according to if-then rules. Nevertheless; episodic memory is related to personal past experiences, so it does not work according to such rules. Even though there are a few examples of the systems with episodic memory, various examples for the system with the other memory systems are common. In that sense, there are a lot of systems with semantic memory such as ‘General Problem Solver’ by Newell and Simon, and the ‘Soar Cognitive Architecture’. Actually, Soar Cognitive architecture has also episodic memory. Nevertheless, episodic memory in Soar Cognitive architecture is not as similar as episodic memory in humans.

> Our goal in adding episodic memory to Soar is to capture the most important functional aspects of episodic memory without necessarily modeling all the details of human episodic memory, many of which are still unknown and may depend on the specifics of the underlying implementation technology of the brain (Nuxoll and Derbinsky, 2012: 225).

Episodic memory in Soar is analyzed in detail in the fourth chapter. In addition, there is a fundamental problem in AI as the deficiency of memory. The problem, which is necessarily to be solved to develop AI, is the frame problem[5]. It is actually a technical problem in AI. The problem is related to changing and unchanging properties in the world as an action is performed. McCarthy (1987) said "the frame problem is that of specifying what does not change when an event occurs". In a word, the problem is simply about whether a formal system is able to deal with complex and changing conditions. There are three aspects of the frame problem, namely; metaphysical, logical and epistemological. The first aspect, metaphysical aspect of it is related to practical studies about finding and implementing general rules for an experience of the world occurring in every day. This aspect is related to how an agent is able to adapt into the world when it comes face-to-face unknown or unfamiliar situations. The second aspect is the logical aspect of the frame problem. The aspect is about the predetermined event or action. That means some causal laws for an event should be predetermined to be able to create a new set of rules for unknown situations. The last aspect of the frame problem is abstract epistemological problem that was in effect discovered by AI thought experimentation. This aspect is about limitation of the scope of the proposition, which is necessary to be known for an action. Additionally, it is related to the representation of the world. As a result, the frame problem is the problem of adaptation into the world due to the fact that a machine is not able to adapt into its environment when it encounters unknown situations or changing actions. Also, matching the machines' beliefs with its action is harder rather than for human beings. Human beings are able to adapt into the world by means of

[5] "Hendricks described the frame problem as a practical problem: "It (the frame problem) concerns with how we retrieve the rigth knowledge at the right time. What accounts as the right knowledge at the a certain time is fixed by the goals, interests and desires of the agent." (2006: 331)

episodic memory. The personal past experiences in episodic memory supports the ability to adapt into the new and unknown situations. An agent is not successful to adapt into its environment when it encounters novel (or unknown) situations without episodic memory. Therefore, the frame problem is an essential issue in AI and we claim that episodic memory can have a significant role in order to solve the frame problem in AI. As already mentioned, the role of memory in AI is the scope of this thesis. The extended information about memory is given in different chapters. Furthermore, in light of these mentioned views, the main point of this thesis is why adding episodic memory into Artificial Intelligence is harder.

In the second chapter, I will explain the development of Artificial Intelligence on the ground of memory due to the fact that memory has a crucial role in the Artificial Intelligence as human beings. There are various examples about memory models, which are related to different high-level cognitive capabilities. By analyzing the development of the memory in Artificial Intelligence and memory models, the importance of episodic memory on Artificial Intelligence can be clearly seen. As mentioned before, episodic memory is more significant for developing the high level cognitive capabilities such as reasoning and decision-making.

In the third chapter, memory and memory systems are going to be defined owing to the fact that it is important to make a distinction between episodic memory and other memory systems not only to understand the role of episodic memory on human cognition but also to be able to develop episodic memory in Artificial Intelligence. Especially, the differences between episodic and semantic memory are analyzed, at the same time; the important point of the chapter is this analyses. It is quite clear to understand episodic memory by virtue of the analyses. Since, semantic memory takes an opposite position to episodic memory. Semantic memory is related to general information whereas episodic memory is concerned with specific and personal information. Therefore, the implementation of semantic memory is easier than the implementation of episodic memory. In spite of the fact that semantic memory is one of the more proper memory systems, episodic memory is more suitable and useful for Artificial Intelligence if the proper episodic memory model can be provided. For this reason, it is clear to see that semantic memory is more suitable for algorithmic systems by virtue of consisting of general information and requiring no personal past experiences. While making the distinction between them, it is obvious to see whether episodic memory is more crucial than other memory systems. The support of episodic memory on the high level cognitive capabilities is inevitable rather than semantic memory for human cognition as well as Artificial Intelligence.

In the fourth chapter, episodic memory in Soar is explained in order to understand the role of episodic memory. To show the differences between Soar cognitive architecture and other memory systems, some examples and their cognitive capabilities are also analyzed in the first part of the chapter. Additionally, memory in Soar is our scope in the second part of the chapter. Since, Soar has also the other memory systems. However, the main part of the chapter is episodic memory in Soar, how it works, the relation between the other memory systems and which cognitive capabilities it has will be in our scope. Episodic memory in Soar is closer to episodic memory in human in spite of the fact that it is not as similar as episodic memory in human. For, some high level cognitive capabilities are supported by episodic memory in Soar. The Soar Cognitive Architecture has ‘perception’, ‘reasoning’ and ‘learning’ cognitive capabilities. These high level cognitive capabilities in Soar are deeply analyzed so that differences between episodic memory in Artificial Intelligence and human will be made clear. Furthermore, I will try to demonstrate the deficiencies of episodic memory in Soar in this part of the chapter since it is not as better as human are episodic memory.

In the final chapter, I will explain the philosophical problems related to the deficiencies of episodic memory in Artificial Intelligence. On account of the fact that memory and Artificial Intelligence are the scopes of philosophy, I think that it is possible to see new and different philosophical aspects when they are into the same perspective in terms of epistemological perspectives. The final point can be that a proper episodic memory technically supports Artificial Intelligence. Actually, in this thesis, I will show episodic memory as a possible solution to the significant problems of AI as the frame problem and consciousness.

CHAPTER 2

HISTORY OF ARTIFICIAL INTELLIGENCE

The field of Artificial Intelligence (AI) has been developing for a long time. It is basically concerned with ‘thinking machines’. Therefore, AI is explained in terms of two aspects, engineering and cognitive. The field has different applications such as: game playing, speech recognition, understanding natural language, computer vision, expert systems, and heuristic classification.

2.1. The Birth of AI

The origin of the idea dated to 2500 B.C. when the idea of ‘thinking machine had emerged although the field was formally named at a computer conference at Dartmouth in 1956 and so it is the new developing area. Kurzweil (1990) mentioned that “Egyptians invent the idea of thinking machines: citizens turn for advice to oracles, which are statues with priests hidden inside”. Additionally, Plato expressed the dilemma between human thought and its relation to the machine in Phaedo before the emergence of the computers when it was about 427 B.C. It is useful to mention about the historically earlier developments in the intelligence machines happening until the Dartmouth conference before giving the definition and development of AI in details. After the idea of thinking machine was emerged by Egyptians in 200 B.C, the elaborate automaton, which includes a mechanical orchestra was developed in China.

2.2. The Development of AI in Modern Time

Blaise Pascal developed the first automatic calculating machine in the world, which is able to add and subtract, in 1642. About fifty years later, an inventor of calculus who is Gottfried Wilhelm Leibniz perfected the Leibniz Computer, which can multiply by performing repetitive additions. This development is significant since its algorithms are still used in modern computers. Moreover, the important figure in the development in the history of AI is Charles Babbage. In 1832, he developed the world’s first computer, which has the ability to solve a wide variety of logical problem. The computer is Analytical Engine. The machine has been developed during time even if it did not get achievement in the first balance. Frege made one of the most crucial developments in 1879. “G. Frege, one of the founders of modern symbolic language, proposes a national system for mechanical reasoning. This works is a forerunner to predicate calculus, which will be used for knowledge representation in Artificial Intelligence” (Kurzweil, 1990**).** Frege had an indirect contribution to AI in the sense that language is one of the most crucial aspects of AI due to the fact that the field requires general program language in order to improve properly. Since, general language program supports an agent’s actions such as reading and speaking.

The first analog computer was designed to solve differential equations by Vannevar Bush and his co-workers. Moreover, Alan Turing and Alanzo Church independently developed the Church-Turing thesis in 1936. Actually, the Turing thesis and Church thesis are two different theses. While Alan Turing wrote Turing thesis, Church wrote the Church Thesis. However, these two dissertations are related to logical- mathematical computing machines. Klenee firstly defined the thesis as the Cruch-Turing thesis in 1967 since Turing thesis is equivalent to Cruch thesis. In 1941, the fully first programmable digital computer, Z-3, was designed by Kondrad Zuse. ‘Logical Calculus of the Ideas Immanent in Nervous Activity’, which is related to neural work architecture for intelligence, was written by McCulloch and Pitts. Von Neumann did the other important development in 1946. He published the first modern paper on the stored-program concept. At the same time, this concept is the crucial point of this thesis since ‘storage’ is related to memory. Therefore, stored-program is useful to the development of AI.

After this development, the various works, which are related to the stored-program, were made. Firstly, Wilkes built EDSAC, which was the first stored-program computer in the world, in 1949. Then, the first American stored-program, BINAC was designed.

> The Binac was the first high-speed electronic digital computer of its type to be completed. It consists of a main computing section, input-output equipment, and a mercury delay-line memory of 512-word capacity. Although designed for a specific purpose, the Binac is well adapted to any type of general mathematical computation (Auerbach, Eckert, Shaw, Weiner, and Wilson, 1652: 12).

2.3. The Development of AI in 1950s

The date 1950 is the most important one for the development of AI since it is accepted as the starting point of AI. In 1950, Alan Turing wrote his popular paper '*Computing Machinery and Intelligence'* to describe a criterion for a machine to be intelligent, which is called Turing Test. McCarthy claimed that

> After WWII, a number of people independently started to work on intelligent machines. The English mathematician Alan Turing may have been the first. He gave a lecture on it in 1947. He also may have been the first to decide that AI was best researched by programming computers rather than by building machines. By the late 1950s, there were only many researches on AI, and most of them were basing their work on programming computers (2001: 4).

From the development of the stored-program concept to Dartmouth conference, a machine designed as similar as human being. Robot-like machine was designed in 1955 to use in the industry area**.** Moreover, in 1956, Stanislaw Ulam developed MANIAC, which was the first program to be able to beat a human in a chess game. Finally, the field of intelligence machine or thinking machine is named as Artificial Intelligence at a computer conference at Dartmouth College[6] in 1956.

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[6]The idea of Artificial Intelligence was firstly emerged in Dartmouth. The young scholars, who were trained in mathematics and logic, gathered to discuss how can it be possible to build computer programs 'behaving' and 'thinking' intelligently' at the campus of Dartmouth College

As already mentioned, between the 1940s and 1950s "the belief that computers should be able to carry out process resembling human thinking and it was the job of the present assemblage to put these promises to test' had been expressed" (Gardner 1985: 139). There had been competition in the meeting. Also, younger generation had seen an atmosphere to think that the machine and programs could do what the human brain does. Some notions such as symbols and data being processed by a program and becoming parts of the program in it had affected to these generations. After the meeting, there have been various advances on the field of Artificial Intelligence. In 1957, General Problem Solver (GPS), which is able to use means-ends analysis[7] for solving various problems such as solving theorems, playing chess, or solving puzzle were developed by Newell, Show and Simon. GPS did not only solve the problem in an efficient way but also it tackled with the problems like a human by means of using the method of the means-ends.

Additionally, one of the most important figures in the field of AI is McCarthy on the base of various contributions to the development of AI. Firstly, he described the Advice Taker, which is accepted as the first complete AI system in his paper, "*Programs with Common Sense"* in 1958. It was designed to search for finding solutions to problems. Secondly, McCarthy and Minksy at Massachusetts Institute of Technology (MIT) founded the laboratory of AI.

2.4. The Emergence of AI

The authorities made various definitions for AI after Dartmouth Conference in Dartmouth at 1966. All participants agreed that Artificial Intelligence is related to a computer, which would be considered as intelligence displayed by humans. It is

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in Hanover, New Hampshire in the summer of 1956. Scholars, who attended the summer school, had played important role in the development of AI such as "John McCarthy who was the first director of AI labs at both the Massachusetts Institute of Technology (1957) and Stanford University (1963)" and Marvin Minsky, Herbert Simon and Allen Newell (Gardner 1985: 138-139).

[7] "Means-ends analysis is a mechanism that is assumed to operate when people solve transformation problems. Its use is affected by the extent to which the goal is clearly specified to the problem solver as a problem state and also by the extent to which learning occurs during a problem-solving episode" (Sweller and Levine, 1982: 463).

clearly obvious that AI is the scope of various academic domains such as psychology, philosophy and computer engineering due to the fact that philosophy and psychology are interested in intelligence while computer engineering is related to the machine side of the field. Therefore, it is not useful to mention about all definition of AI, however; according to Russell and Norvig,

> The field of Artificial Intelligence, or AI, attempts to understand intelligent entities. Thus, one reason to study it is to learn about ourselves. But unlike philosophy and psychology, which are also concerned with intelligence, AI strives to build intelligent entities as well as understand them. Another reason to study AI is that these constructed intelligent entities are interesting and in their own rights (1995: 3)

The definitions of AI is basically divided into four categories by Russell and Norvig (1995); namely, (1) a machine or system can think like human, (2) a machine or system can act like human, (3) a machine or system can think rationally, and (4) a machine or system can act rationally. Actually, there are mainly two types of AI defined by Searle. These types are called as weak AI and Strong AI. Searle said that

> According to weak AI, the principal value of the computer in the study of the mind is that it gives us a very powerful tool. For example, it enables us to formulate and test hypothesis in a more rigorous and precise fashion. But according to strong AI, the computer is not merely a tool in the study of the mind; rather, the appropriately programmed computer really is a mind, in the sense that computers given the right programs can be literally said to understand and have other cognitive states. In strong AI, programmed computer has cognitive states, the programs are not mere tools that enable us to test psychological explanations; rather, the programs are themselves the explanations (Searle, 1980: 2).

Strong AI is related to that machines, which are capable of real thought and consciousness. In other words, the machine is able to have the capability of 'rational thinking'. Strong AI consists of machines, which are as similar as human beings in terms of rational thinking. On the other hand, weak AI is related to that machine, which is capable of some components of intelligence. It means that the machine is able to act rationally. AI is definitely related to all intelligent components. “AI currently encompasses a huge variety of subfields, from general purpose areas such as perception, and logical reasoning to specific tasks such as playing chess, proving mathematical theorems, writing poetry, and diagnosing diseases” (Russell and Norvig, 1995: 4). Thus, AI has to be related to one the most important aspect of human cognition that is memory.

2.5. The Development of Memory in AI

Memory has a significant role on human intelligence. It helps human beings to be able to solve problems. It is crucial to analyze whether intelligent machines have memory or not. Additionally**,** memory that they have is explained and whether their memory is as similar as human memory is analyzed. It can be clear to say that there have been various memory systems (or models) during the starting point of the Artificial Intelligence. Hence, it is necessary to analyze the machine in terms of memory.

Charles Babbage invented the first program, which is with the capability of ‘storage’,[8] as the ideas of addressable memory, stored-program and conditional jumps in 1832 even though von Neumann is accepted as the first person to write about the stored-program concept in 1946. The program is called as the Analytical Machine[9], which is able to sign and magnitude representation for numbers in the store. “The machine had a memory store capable of holding some 1,000 and 50 digit number” (Freedenberg: 2008: 22). The main function of the program is actually to solve various logical and computational problems. Bromley claimed “Analytical engine makes a clear distinction between ‘the store’ in which operands and results are held between operations, and ‘the mill’ to

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[8]Charles Babbage is Cambridge Mathematician. Gardner said that “One such character was the brillant and prescient Cambridge Mathematician. Charles Babbage who devoted many years to devising an automatic table calculator which could carry out the complicated computations needed for navigations and bollistics” (1985: 142).

[9]In Standford encyclopedia of philosophy, Copeland (2008) said that“Babbage’s proposed Analytical Engine, considerablymore ambitious than the Difference Engine, was to have been a general purpose mechanical digital computer. The Analytical Engine was to have had a memory store and central processing unit (or mill) and would have been able to select from among alternative actions consequent upon the outcome of its previous actions.

which they are brought to perform arithmetic operations. The store and the mill correspond closely to the memory and central processing unit (CPU) of a modern computer'' (1982: 198).

The other important figure in the development of the stored-program is Alan Turing. He developed the principle of the modern computer in 1936. He designed an abstract digital machine with a limitless memory, which has also scanner to move throughout two sides: back and forth through the memory; therefore, it is able to read what is found, and written further symbols. Furthermore, the scanner works by virtue of a program of stored instructions in the memory. This stored-program concept and the all types of Turing's computing machine are known as Turing Machine. Claude Shannon is also another important figure in the development of AI. In 1938, he published a paper titled as 'A Symbolic Analysis of Relay and Switching Circuits'. The paper about the complex electrical systems was written to make mathematical analysis of properties of such networks. These systems consist of circuits so that they work with on-off switches. Shannon says, "In the control and protective circuits of complex electrical systems, it is frequently necessary to make intricate interconnection of relay constants and switches" (1938: 713). Additionally, any circuits automatically perform complex operations. The aim of the program is to find a circuit, which has an interconnection with the given characteristic. "Method will also be described for finding any number of circuits equivalents to a given circuit in all operating characteristics" (Shannon, 1938: 714). The machine was actually defined by Shannon according to truth-logic operations. Examples of these systems are commonly automatic telephone exchanges and industrial motor-control equipment. Actually, there were some works on neural architectures for intelligence.

McCulloch and Pitts made one of the architectures in 1943. They wrote the article titled "*Logical Calculus of the Ideas Immanent in Nervous Activity"* in which they discussed neural-work architecture for intelligence. In other words, we concerned with a model of artificial neurons. At the same year, Von Neumann reported EDVAC, which is an electronic stored-program general-purpose digital computer[10]. He worked on developing the idea of a stored program. Therefore, a computer could be worked in terms of instructions, which are stored in the computer's internal memory. Thus, he showed that it is possible to work binary logic and arithmetic together in storing information so that the same language for data in the program and storage in the computer should be used. After the emergence of EDVAC, as already mentioned, the first modern paper on the stored-program concept were written by von Neumann and then he started to make researches on computers. Von Neumann's machines (architecture) are important for the development of intelligence machines (or AI) due to fact that his architecture defines a general structure to be followed by a computer's components such as hardware, programming, and data.

Von Neumann's architecture consists of three main parts: (1) memory subsystem, (2) arithmetic logic unit and (3) control unit. These three main components interact with each other. While main memory stores data and instructions, the control unit decodes the instructions taking place in the memory and they execute because of the unit. Furthermore, arithmetical logic unit does the arithmetical logic operations for the program. The subsystems of memory consist of four parts. The first part is that the memory is called as Random Access Memory (RAM). It is made up of many storage units, or memory cells, with fixed size and also each cell has its own address as 0, 1, and 2. Additionally, the storage unit has two important characteristics, which are related to where it takes place (ıts address) and what it stores at the given location (its contents). The second part of subsystem of memory is memory width. It is related to how many bits each cell is. For example, one cell is typically 8 bits (one byte). The third part is address width that is related to how many bits are used to represent each address. In other words, memory size is equivalent to the address space. The last part is the address space that is the unique number to identify memory location. Memory of von

[10] Copeland (2008) states that "Von Neumann was a prestigious figure and he made the concept of a high-speed stored-program digital computers. The electronic stored-program digital computers refer to 'von Neumann machines."

Neumann machine has also two operations, namely, address (fetch) and store (address and value). The program fetches a memory cell, which has its own address. In addition to that, the program stores the specific values in memory cell.

Memory has become crucial aspects for AI after this development due to the fact that Turing set memory as a condition for a machine that should be as intelligent as human when he proposed a satisfactory definition of intelligence in 1950. "Turing defined intelligent behavior as the ability to achieve human level performance in all cognitive tasks, sufficient to fool an interrogator[11]"(Russell and Norvig, 1995: 5).

The machine had to get some crucial cognitive capabilities. Firstly, the machine is able to process in natural language. In other words, it can successfully communicate in some human language such as English or Turkish. Secondly, the machine is able to make knowledge representation so that it can store information provided before the interrogation or during it. The third capability is automated reasoning. The machine can use the stored information to answer questions and make new conclusion by means of that ability. Lastly, the machine gets the ability, machine learning on account of the fact that the machine requires not only to adapt to new situations or circumstances but also detect the patterns.

Machine intelligence needs memory in order to achieve the goal and solve problems. Another step in the development of intelligence machine is the General Problem Solver (GPS) by Newell, Shaw and Simon in 1957. The computer is programmed to solve problems like human does. While developing the versions, the GPS was designed to be able to solve various problems such as solving theorems, playing chess, or solving puzzles. That does not mean GPS was able to solve any problems given to it. On the contrary, if the certain types of problems

[11] "A standart version of the Imitation Game involves a man, a computer, and a human interrogator. The interrogator stays in a room apart from the man and the computer and must on the basis of answer to questions that he puts to each via a teletypewriter decide which respondent is the man and which respondent is the computer. In this version of the game, which is often called the 'Turing Test', the basic question which replaces the question 'Can machines think? might be put, 'On the average after n minutes or m questions is an interrogator's probability of correctly identifying which respondent is a machine significantly greater than 50 percent?" (Moor, 1975: 249).

and their solutions were formulated for GPS in clear steps, GPS could solve the problems. The process should go step by step from state to state in order to find proper solutions. Until 1969, GPS had been modified a number of times to solve other problems. Moreover, the GPS follows similar processes humans do. According to Gardner (1985), "we as humans are of course general problem solver per excellence, and if AI researchers are to succeed in developing intelligent machines, these machines will have to behave more like us in this regard". As a result, the development of GPS shows that it becomes more general than previous one that is Logic Theorists[12].

2.6. Expert Systems

There are other improvements on AI, expert systems, which are taken by AI researchers. In 1960s, Marvin and his student, Evan had the important role in the development of AI. Evan designed a complex program in the machine, which had a huge memory to solve visual sort analogies. The figure, which had some relation with the others, was shown to the program then it selected another figure, which completed the visual analogy. "The program is shown A is to B and must then pick that picture out of five which indicates the relations that obtain between C and D" (Gardner, 1985: 152). The program firstly makes a description about both A and B then it makes a distinction between them. After that, it transforms the rule to C by means of identified differences between A and B. The aim is to get the same description with one of the five numbered patterns. In light of these mentioned information, the program had to use memory to achieve the goal.

The other significant invention in the development of AI is made with the collaboration of Buchanan, Feigenbaum, and Lederberg at Stanford University in 1965. The invention is called as DENDRAL project. DENDRAL was designed to analyze organic compound. In addition, Lederberg (1987) said that DENDRAL was not only an exemplar of expert systems but also a modeling problem-solving

[12]In the 1950s, Newell,Shaw and Simon introduced their program, Logic Theorist. The computer searches logical way for proof of the theorems. Also, the program tackled the theorems mentioned in Whitehead and Russel's 1990 book Principia Mathematica. The computer program firstly implemented proofs of abstract statements in Dartmouth College (Gardner, 1985).

behavior. For this reason, it tries to solve problems like human beings while using the stored knowledge about the chemical processes in order to make prediction. Moreover, the program has two main functions. The first one is that it formulates a hypothesis, which is related to the molecular structure. The second function is that the hypothesis is tested by it to be able to make relevant prediction.

Expert system means that a machine is the expert of any special domain such as organic. Russell and Norvig describe the expert system as knowledge-based system[13] in their book, *Artificial Intelligence A Modern Approach*. DENDRAL is the first expert system because of formulating extensive knowledge of molecular-structure analysis. The aim of the program is to make an experiment on knowledge by means of producing problem-solving behavior. With working on the development of DENDRAL, Meta-DENDRAL, which is a type of learning programs, was investigated to devise new rules for DENDRAL automatically at one year later. According to Russell and Norvig, "The significance of DENDRAL was that it was arguably the first successful knowledge-intensive system: its expertise derived from large numbers of special-purpose rules" (1995: 22). Furthermore, there is a relation between the domain knowledge and the area of understanding of natural language. Since, the program for understanding of natural language is the expert system at the same time.

One of the most important Natural Language Understanding (NLU) program is SHRDLU, which was investigated by Winograd in the early 1970s. The program was not only natural language understanding program but also a kind of software robot that is able to work in a toy block world. Additionally, it is a program that is able to show various intelligent behaviors. While working, the program is firstly asked the question about its world. Then, it answers questions, rules out command and shows the result. Moreover; according to Tanaka, Tokunaga and Yusuke,

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[13]"Such approaches have been called weak methods**,** becuase they use weak information about the domain. For many complex domains, it truns out that their performance is also weak" (Russell and Norvig, 1995: 22).

> It could understand English dialogue input from keyboards (no speech input) according to which it carried out very simple tasks such as "Pick up red block on the table" and "Put it in the green box" by building its action plan and executing it. The system could also answer simple queries about the current state of the toy block world. It could resolve anaphoric ambiguities in the input sentence. SHRDLU demonstrated the promising future of NLU research at that time. (2004: 429-430).

The program is different from the others because of the fact that it cannot work like GPS or work with the key words. It works limited domain to understand experts. It also uses its own linguistic knowledge so that it can carry out a complex set of instructions. SHRDLU has a significant role on the development of AI due to fact that it is able to carry out the numbers of actions. Moreover, the program cannot only put the syntactic segments into meaningful statements but also describes the objects with the nouns by means of the actions that are described with the verbs. However, SHRDLU does not make a semantic relation between the propositions since it does not know the differences between 'AND', 'THE', and 'BUT'. In light of these mentioned views, SHRDLU is related to domain knowledge rather than general knowledge. In 1970s, the second period of the field of AI had started with Winograd's SHRDLU due to fact that the trend in AI shifted from general knowledge system to expert knowledge systems, which was shifted by the program. Additionally, the effects of the procedural and declarative approaches have emerged. Gardner said, "At the same time, there was another vital issue, which is the increasing use of a top-down approach to understanding

2.6.1. The Script

Schank presented another crucial achievement in AI. Schank and his colleagues worked on the development of understanding natural language on the ground of memory. According to Gardner, "Schank claimed that all verbs in everyday speech could be analyzed in terms of twelve primitive actions (such as; move, ingest, grasp), which concern the handling movement or transference of the things, abstract relationships, and ideas" (1985: 168). People can generally understand the language by means of these primitive actions so that one can focus on the semantic rather than syntax. While working on the research, the notion of 'script' is defined so as to give an account for knowledge about mundane situations. In a word, scripts are knowledge representation systems to define familiar everyday situations such as sitting our own chair, getting an appointment from a doctor, and going to a restaurant. Schank and Abelson say, "A script, as we use it, is a structure that describes appropriate sequences of events in a particular context" (1975: 151). A script is simply related to what we know about the certain situations and how we behave in the situations. For example, in a conference, a speaker follows the script of speakers while a listener follows the script that is proper. Therefore, the listener or the speaker does not have to think too much about the situations, which is related to the conference whenever they take place in a conference. The new information or input is added into the script of the conference instead of thinking too much. The most significant characteristic of scripts is 'being a kind of memory structure'. They store knowledge about certain situations that we already have. Schank and Alben described a script as a kind of storehouse of old experiences of certain types to be able to encode new experiences of the same type. In a sense, scripts are not only predetermined sequences of actions, which define a well-known situations but also expectation about what will happen next in the well-known situations. A script is defined as a little story due to the fact that the story is the most important aspect in human memory and human interaction naturally made with a language. Every day, human beings interact with each other by telling stories. When a story makes interaction in language, all knowledge human beings have is put into story so that human beings are able to construct and retrieve them. A computer or a program is able to understand stories about the typical situations by means of scripts.

Schank and his colleagues designed a program, which can answer quotations, read articles, and give summary about stories by the means of using scripts. In other words, the program is related to understand English or natural language by virtue of the notion of a script. The program is defined as SAM[14] (Script Applier Mechanism). The program is able to make inferences in domain about which it knows and also to complete causal chain between inputs. “SAM identifies the script to be used (by using Riesbeck’s request format) and fills in the identified script with the new inputs as they are received” (Schank and Alben, 1975: 153). Giving an example[15] of SAM’s input and output is better to understand easily.

Input: Alan went to a coffee shop. He seat down. The waiter come to table and gave menu to him. Alan ordered a cup of Turkish coffee. He was served perfectly. Alan left a large tip. Then, he left the shop.

Outputs:

Q: What did Alan drink?

A: Turkish coffee

Q: Who gave Alan the menu?

A: The waiter

Q: Who paid the check?

A: Alan

Q: Why did Alan get a menu?

A: to give an order.

Q: Why did Alan give a large tip to the waiter?

A: Since, the waiter made the perfect service to him.

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[14] Schank and Alben siad that “SAM was written by Chris Riesbeck, Richard Cullingford and Wendy Lehnert (1975: 153).

[15] The example is made according to the example given in the book ‘Scripts, Plans and knowledge’ written by Schank and Abelson in 1975.

The summary of this process is that Alan went to the coffee shop and drink Turkish coffee. Schank and Alben said that;

> This program runs on the PDP-10 at Yale. It currently has only a small amount of knowledge and small vocabulary. But we feel encouraged that our scripts theory is workable because of the simplification in the inference process that has resulted from the use of scripts. (1975: 154).

The program has a crucial role on the development of AI in terms of memory. Since, the program is able to make a proper inference and give good solutions by the means of using the story in memory. It is obvious to say that a script theory is precious to develop AI with memory.

2.7. The Achievements in 1970s and 1980s

There are various developments in AI, especially expert systems, which were also related to perception in 1970s. Cornell Frank designed a visual perception machine, which has ability to recognize the letters in front of its eyes. Pactrick Wiston designed a program to not only recognize the object in front of it when examples and counterexamples are shown but also to make differences between these opposite sides. David Waltz designed a program, which is related to analyzing of the screen. The program can recognize the different objects in the same screen. Finally, the other visual program was designed by Marr to show the characterization of visual systems. According to Gardner, “Marr was impressed by Chomsky’s theoretical approach to what language is and how any organization can learn a language” (1985: 170). In the light of these mentioned views about the developments in 1970s, it is clear to say that there were significant developments in the field of AI on the bases of the expert systems.

Kurzweil (1990) says, “More than 5,000 microcomputers were sold in the US, and the first personal computer with 256 bytes of memory was introduced in 1975”. Weizenbaum perfected ELIZA in order to simulate a Rogerian psychotherapist in 1976. Also, he published *Computer Power on Human Reason* to argue that building an intelligent machine may be unethical.

In 1980s, the other trend has started developing in the field of AI. All researches were focused on the parallel architectures and methodologies to solve problems.

2.8. Cognitive Architectures

Cognitive architectures are other perspective of the development of AI. Cognitive Architecture[16] is a scope of the cognitive science that works on the nature of thought and the appearance of intelligence. Cognitive architecture is defined as the design of structural models of behavior. It naturally consists of two parts; namely, (1) cognitive and (2) architecture. While cognitive is mostly related to language capabilities and the acquisition of skills in human beings, architecture is called as modeling or computational design of mind, intelligence or cognition. The modeling or programming of cognitive architecture is theoretical not related to software engineering. According to Gluck, the roots of this perspective emerged in 1958. He said that "the idea that the mind should be rigorously studied in modeling and simulation traces its intellectual roots to the landmark Newell, Shaw and Simon (1958) paper, in which they proposed information processing models implemented in the computer code as explanations of human problem solving" (2012: 11).

Additionally, Lewis said that

> If we take the start of contemporary cognitive science to be the mid-1950s, it is sobering to note that cognitive architectures have been pursued for about half of the field's existence: it has been nearly 30 years since the publication of Anderson's *The Architecture of Cognition,* and over 20 years since Newell's Unified Theories of Cognition (2012: 11-12).

Cognitive psychologists divide mental operations into two main parts. The first part is lower level cognitive tasks, which consist of pattern recognition,

[16] "Cognitive architectures are broad, domain-general theories of the mechanisms and structures that enable mind and intelligent behavior" (Gluck, 2012: 11).

perception, and some forms of learning as habituation. The second part is high-level cognitive tasks that are more different that lower levels. They consist of complex learning and memory, communication, and problem solving and task acquisition, and language. Cognitive architecture is divided into these two categories. Real said that

> Since the 1940s the dominant model of the human economic decision-making has been expected utility model first articulated by Bernoulli (12) in 1793 and axiomatized by von Neumann and Morganstern (13) in 1945 as a part of their development of game theory" (1991: 981).

However, the scope of this thesis is cognitive architecture with high-level cognition task rather than with lower level cognitive tasks.

The most important cognitive model with the high level cognitive tasks is 'The Soar Cognitive Architecture'. It consists of memory, episodic and semantic memory; at the same time, it also has the capability of problem solving and reinforcement learning. The architecture is functionally more close to human intelligence. This cognitive architecture will be in the scope in terms of its memory, especially episodic memory in the fourth chapter. In the light of these mentioned views about the development of AI, it is obviously say that there are various important achievements in the field of AI. The field has been developed since the starting point of the idea. In this chapter, the historical background and the significant achievements in AI have been mentioned.

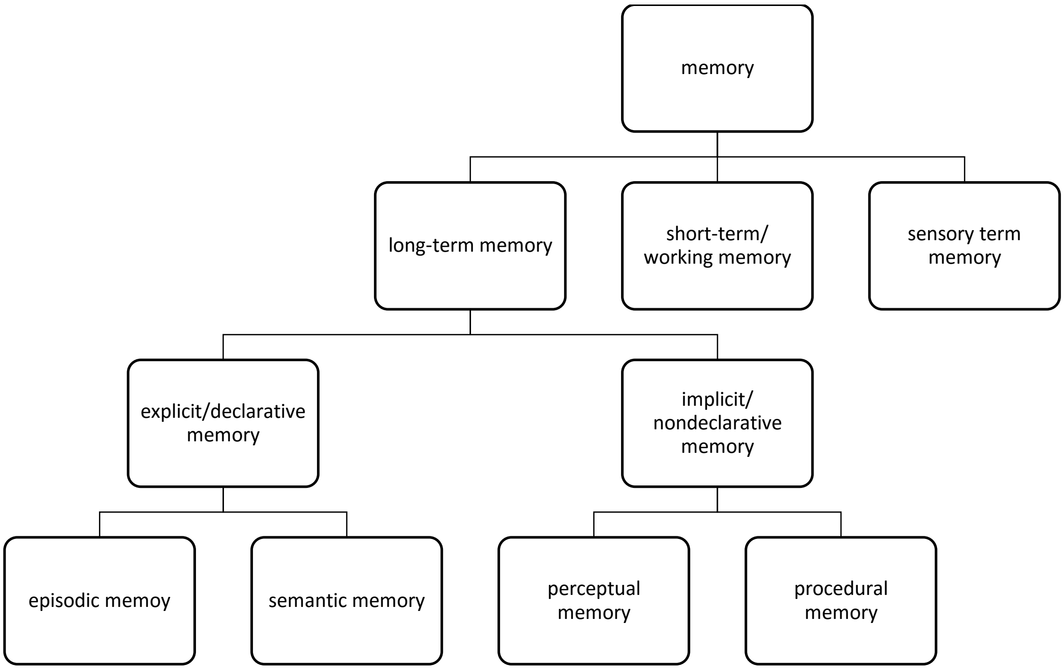
In the next chapter, the background of memory, and memory models are going to be mentioned due to fact that it is essential to understand memory so as to be able to accelerate the development of AI and make cognitive architecture closer to human intelligence.

CHAPTER 3

MEMORY and MEMORY SYSTEMS

Memory is one of the most significant aspects of human cognition**.** Some crucial cognitive capabilities, learning, reasoning, perception and attention and so on, are not developed without memory. In other words, memory is related to understanding of human own world, solving problems, reasoning and communicating. Richardson, Goldsmiths and Byrok describe memory as "the 'glue', in effect, that holds our intellectual process together, from perception, attention, and language, to reasoning, decision making, and problem solving" (1980: 3828). Generally, in everyday language, memory is defined as a box into which our experiences, our knowledge and our senses are stored. Since, we need to store information about our life, our location, which data we see, when we meet our boyfriend and what the telephone number of our close friend is. Memory has three main capabilities as encoding, storing and retrieval. These capabilities can be considered as stages or order. Since, the information is firstly encoded to be stored in memory; secondly, the encoded information is stored in memory for temporal delays, permanent or temporary. Finally, the stored information is retrievable from the storage when it is necessary. It is significant to say that not all our experiences, knowledge and senses can be encoded, stored or retrieved.

Memory is complex and partial entity rather than simple. In a sense, there are three main memory subsystems differing from each other in terms of their storing capacities, their functions and their storing period. The memory systems can be shown on a simple table to easily cover all information about the systems and the subsystems that is going to be given. The memory systems are hierarchically given in categorical way in the table so that the system can be clearly seen.



Table

The first is sensory memory, the second is short-term memory and the third one is long-term memory. However, the memory consists of various subsystems; these subsystems interact with each other even though they have different functions. The interaction between these memory systems can be actually analyzed in their definitions. Additionally, all memory systems have these aforesaid stages. To being with, sense, be visual, hearing, taste or so on, comes from the environment to sensory memory. Sensory memory is for recoding the information that comes from all the senses such as taste and sound. Because of that, there are different memories for each sense. Iconic memory is related to visual impression while echoic memory is related to sense of hearing. If we look at the process in short-term memory, the sensational information enters into sensory memory before short-term memory to be encoded then the information is held in sensory memory for a short time, about 30 seconds before being transferred into short-term memory. In contrast, short-term memory holds information for a few seconds or minutes. It is defined as "the temporary storage of small amounts of material over brief delays" (Baddeley, Eysenck and Anderson 2009: 9).

Information is immediately encoded, stored or delayed after a short time after information is passed into short-term memory from sensory memory. After immediately encoded and stored, the information is transferred into the long-term memory. However, there is no such obligation that the information firstly enters into short-term memory. They can directly enter into long-term memory. Long-term memory keeps in all information coming from short-term memory and direct information for a long time or over a life's time. The certain information is that there is distinction between short-term and long-term memory in terms of how long memories have been stored. In addition to that information, long-term memory also has its own subsystems.

There are two main long-term memory systems, which are declarative (explicit) memory and non-declarative (implicit) memory. It is natural to mention the distinction between declarative and non-declarative memory. The most important difference is that explicit memory requires 'being conscious' whereas implicit memory does not need **'**being conscious'. That means the retrieval can unconsciously occur. Since, 'implicit memory: a memory that influences us even though it is not present in the consciousness' (Lieberman, 2012: 511). Moreover, implicit memory is related to conditioning and skills. On the other hand, explicit memory is related to remembering of personal experiences or fact. "Explicit/declarative memory is a memory that is open to intentional retrieval, whether based on recollecting personal events (episodic) or facts (semantic)" (Baddeley, Eysenck, and Anderson 2009: 10). Lieberman claimed that "The distinction between implicit and explicit memory was made by Graf and Schacter in 1985" (2012: 354).

Declarative/explicit memory is divided into two parts, namely; episodic and semantic memory. Episodic memory is related to personal experiences or memories; and semantic memory is related to facts, and general knowledge. However, the distinction between episodic and semantic memory made by Endel Tulving (1972, 2001) is explained in detail in these next sections.

At the same time, long-term memory, actually implicit memory, has also two components, which are perceptual and procedural memory. Procedural memory is interested in how to know how to do things. According to Lieberman, “procedural memory refers to changes that occur on the output side- once having recognized a stimulus, we become faster at deciding how to respond and then initiating that response” (2012: 355). In detail, these parts of implicit memory, like its own, are not based on recollection or remembering**.** Rather it is based on reflection on performance. Therefore, procedural memory is related to abilities such as riding a bicycle, driving a car, writing, playing the piano and so on. In a sense, procedural memory supports to recognize and immediately give output. Since, output relating to performance can be improved with making practice. In contrast, perceptual memory is concerned with sensory input rather than output. It supports to improve and recognize the sensory input by means of experience. It is also significant to decline that all progress in perceptual and procedural memory occur without conscious. Lieberman explained “without conscious, like that sometimes our some past experiences unconsciously affect us such as unconscious feelings of greater liking for familiar face” (2012: 392).

Working memory is replaced with short-term memory because the memory performs various tasks in active way.

> Working memory is the capacity to manipulate and maintain information over shorts periods (2-15 seconds) in order to support simple memory task such as remembering a telephone number, or more general cognitive task such as problem solving, simple reasoning and reading (Dosher 1980: 4284).

Working memory has significant role in solving arithmetical/mathematical problems and language learning. For example, working memory works when you try to find the conclusion of 446+225. Therefore, the working memory is not simple as well as the other memory systems.

Moreover, Baddeley and Hitch introduced Multicomponent Model of working memory in 1974. There are three components of the model. The first is related to store the sounds of words, the second is to store visual information and the third is related to transfer the information into long-term store. These specialized subsystems have their own names. Baddeley and Hitch called them as,

A Phonological loop is concerned with the sounds of words, which are pronounced so that it stores speech-based information.

A visual-spatial sketchpad is concerned with the visual material such as picture or appearances. In a sense, it is related to remember visual appearance as human face and location of stores.

A central executive is the controller of these two systems. It supports to transfer the information from this system to long-term memory. Additionally, "it plays a central role in further processing of this information in task such as reasoning and understanding language" (Lieberman 2012: 327).

In light of these views, it can be said that working memory is an important part of the human memory system since it supports to perform complex cognitive abilities even though it temporarily store the information. To conclude, all information given about memory and memory systems are related to get general perspective about human memory systems. Memory is a complex system rather than a simple system because of having various memory systems. Memory can be categorized as systems and subsystems.

The distinction between episodic and semantic memory, which are the two parts of explicit memory, will be analyzed in detail. This analysis is important in order to understand the role of episodic memory in agentive systems, especially Artificial Intelligence.

3.1. Episodic Memory versus Semantic Memory

The memory is mainly analyzed into two parts as long-term memory and short-term memory. Also, the long-memory consists of two parts. The declarative (explicit) and non-declarative (implicit) memories are the parts of long-term memory. The declarative memory has two different components, which are episodic and semantic memories. Tulving (1972) is the first psychologist who described the distinction between episodic and semantic memories. "Tulving believed that episodic and semantic memories differ in similarly fundamental ways" (Lieberman 2012: 358).

There are so many differences between the two kinds of memory systems. Therefore, Tulving analyzed the distinction between episodic and semantic memory in terms of differences in information, differences in operations and differences in application in the third chapter of his book *Elements of Episodic Memory* in 1983. Moreover, he worked through these differences in a specific part, called "Argument for Differences", in the third chapter. I will propose certain points in order to show the difference between episodic memory and semantic memory from a different perspective. I argue that the distinctions between episodic memory and semantic memory can be analyzed in term of their (1) definitions, (2) types and capacities, (3) the consciousness to which they are related and (4) functions and (5) applications on Artificial Intelligence.

3.1.1. Definitional Distinction

There are various definitions, which were given by many researchers for episodic and semantic memory. Actually, they show differentiation from each other in terms of their definitions or context. Before starting to examine the differences between two memory systems, it is a pertinent remark to say that Tulving had changed the definition of episodic memory from 1972 to 1999. In 1972, it was defined as:

> Episodic memory is an information processing system that a) receives and stores information about temporally dated episodes or events, and about temporal-spatial relation among these events, b) retains various aspects of this information, and c) upon instruction transmits specific retained information to other systems, including those responsible for translating it into behavior and consciousness awareness (Tulving 2002: 20).

In 1999, Tulving defined episodic memory, as it is a past-oriented memory system allowing to mental time travel through subjective time including the past and the future. Also, it supports re-experiencing by the virtue of auto noetic consciousness (2001: 20).

Episodic memory is determined as the act of remembering the person's own past experiences whereas semantic memory is related to the knowledge of the world. Therefore, the information in the episodic memory is an event or an episode. Tulving said, "the information in the episodic memory refers to represent events in the rememberer's personal past, and may provide a basis for defining an individual's personal identity" (1984: 225). Nonetheless, facts, ideas, concepts, and rules are the information in semantic memory. Also, there is no connection to the personal aspects. It relates to who made firstly mentioned about episodic memory while episodic memory relates to where you had your eighteenth birthday. Additionally, episodic memory contains one's feeling occurring about those events but semantic memory does not.

> …... a feeling that is missing when one thinks about the knowledge in semantic memory (Tulving, 2001: 19).

Episodic memory uses experiences as a source but semantic memory uses the facts, ideas and concept as source since experience consists of feelings. For example, when storing episodes, which are relating to your first car road trip, you store which feelings you have during the trip. Furthermore, the information, which is an event, in episodic memory, occurs in time. Hence, there is a spatiotemporal relation between the events and the information in semantic memory that does not have to be temporal. Instead, it is defined as conceptual. Tulving mentioned, "The organization of knowledge is defined by many relations that could be classified as conceptual" (1984: 225).

Episodic memory contains subjectively sensed time because of the fact that episodic memory is related to the past experiences while semantic memory are related to general knowledge that does not require subjectively sensed time. For example, the information about the rising of the sun is related to the knowledge of the world. Subjectively sensed time is not necessary to know this information since it is related to general knowledge instead of experience. ‘When one recalls a fact learned in the past, re-experiencing of the learning episode is not necessary’ (Wilson and Keil, 2001:278). Experience requires subjectively sensed time. Therefore, it is possible to think that experience and feelings, or senses are connected to each other. Additionally, the time is required by episodic memory is not calendar time or clock but it requires the subjective or mental time. Semantic memory involves universal deliverance about the facts, ideas and so on whereas episodic memory involves special deliverance related to the personal experiences. For example, it deals with ‘What is the book?’ On the contrary, episodic memory concerns with ‘Which book did you read?’ It is quite obvious to say that episodic memories are related to personal experiences whereas semantic memory includes facts.

Episodic memories are about information of what happened, when it happened and where it happened in contrast to semantic memory. These w-questions based on episodic memory are called as “what are known as the www criteria” (Eysenck 2012: 156). In a word, the information takes place in episodic memory in terms of what occurred, where it occurred and when it occurred. The information about what was done with your best friend is stored in terms of these aspects. To illustrate, Lisa and her best friend went to dance in Manhattan last night. However, semantic memory is not related to specific or personal events like that. It only contains general information about the place of Manhattan rather than the specific or detailed information. Therefore, immediate experiences are stored by episodic system while general knowledge is registered by semantic system by the means of referential events and language. Since, language is related to semantic memory**.** In a word semantic memory contains propositional aspects while episodic memory does not. An example for semantic memory is that I remember that I had a few bicycles when I was a child. An example for episodic memory is that I remember my red bicycle. The two examples are different from each other even if they look like similar. The reason why they are different from each other is that the example for episodic memory consists of memories while the example is related to propositional knowledge. In other words, the example is related to episodic memory contains my past memories about my red bicycle. The information in the episodic memory is changeable while semantic memory does not have changeable information. That means the fact that the information in episodic memory is specific personal events so they can be modified, changed, recoded and also reused in during the time. The general knowledge and facts are the information in the semantic memory so that they are stable, unmodified and unchangeable through time. For example, the information about which city is the capital city of Turkey is an example for unchangeable information due to the fact that the capital city of Turkey does not change anytime. The capital city of Turkey and the information about it are always the same. It is not related to subjective information so it is not different from the situation-to-situation or person-to-person. In contrast, the information about the first trip to Paris with her boyfriend during time so that it is accepted as changeable information. A person can modify or reevaluate his information stored in episodic memory. For example, suppose that someone travelled to Paris with her boyfriend and we analyze two situations. The first situation is that their relation is going on and the second situation is that the relation is finished. In case the couple finished their relation, the information about the first trip in Paris can change. In the first situation, the person may lovely remember their past experiences in Paris; however, she may differently remember her memories in Paris in the second situation. Therefore, the first perspective knowledge is stored in episodic memory. Tulving mentioned that "registration in episodic memory is based on first perspective or immediate knowledge while semantic memory registers second-hand knowledge" (1983: 41).

Moreover, the one more specific feature of episodic memory is "re-experiencing" by means of auto noetic awareness. It supports people to mentally experience or remember their own past experiences again and again. For example, whenever she hears and sees something about Paris, she mentally re-experiences the moments happening in Paris.

> The original experience may involve emotional arousal (e.g. fear) that was associated with the event and this emotion may be remembered when the linked scenes, constituting the episode, are later retrieved. The experiencer may also be vaguely aware during the episode itself of the more general spatio-temporal context in which the event is set and how it fits into his or her life story (Mayes and Roberts, 2001: 1395).

Therefore, the reference point of episodic memory is one's self while universe is the reference point of semantic memory. Since, semantic memory does not take episodes or particular events as the reference.

The most important concept in definition of episodic memory is also 're-collective experience'. "Recollection[17] involves re-experiencing particular contextual details of a past event, such as the tone of voice in which a statement is uttered in the kitchen at nine o' clock" (Richardson and Bjork 1980: 3828). Episodic memory is related to remembering or recollecting. According to Tulving (1983), remembering starts with an event, which is perceived, by the rememberer and it ends with re-collective experiences. In a word, a person perceives an event before starting to remember, and then, he mentally scans the stored episodes; then remembering finishes with the re-collective experiences. For instance, suppose that a boy broke his left arm while doing Taekwondo and he cannot do Taekwondo for a long time. One day after the accident, his friend asked how it happened so he starts remembering his memories about the accident. He started to tell how it happened. He said that he felt down on his left arm because of slipping of his left foot while giving a kick through a target at a high level. Then, he felt pain so he was taken to hospital. Therefore, at the end, he recollects experiences related to the accident. In a sense, it can be mentioned about re-

[17] The 'contents of recollection, or ecphoric information (Tulving, 1983), represent a type of knowledge; knowledge of and about personally experienced past events as experienced, interpreted, and understood by the rememberer at the time, and modified by subsequent events and conditions of retrieval' (Tulving, 1989: 4).

collective experiences in a semantic memory but it is not about remembered past rather about actualized knowledge. As a result, the components in definition of episodic and semantic memories show that there is a crucial distinction between them.

3.1.2. Distinction in Types and Capacity

Episodic and semantic memories are different from each other in terms of their types even though they are subcomponent of the long-term memory. Firstly, episodic memory is past-oriented system while semantic memory is present-oriented system. Atance (2008: 99) describes episodic memory as “the only form of memory that is actually oriented toward the past.” Episodic memory refers to past episodes or events happened in the past. What you wore in the last marriage anniversary ceremony is an instance for episodic memory. However, semantic memory is about present events. Semantic memory is not related to past events. For example, ‘what is the capital city of Turkey?’ is the present event. Actually, there are a lot of related questions for semantic memory, which can be asked and their answer can be easily found.

There is a most important issue about episodic memory. It is the only memory type that is unique to human being, but other types of memory, especially semantic memory, is common for non-human beings. Not only human beings but also non-human beings are able to use knowledge about their worlds. “Semantic memory is the closest relative of episodic memory in the family of memory systems. “It allows humans and non-humans to acquire and use knowledge about their world” (Wilson and Keil, 1999: 278). The reason why episodic memory is unique to human beings is because it requires self-consciousness, since it is a crucial component for storing episodes and retrieval. Additionally, self-awareness is related to introspection that is a process-taking place in humans’ minds since being aware of the self requires introspection so that humans are able to get direct knowledge of their own minds. “The term ‘introspection’ might be defined as the direct, conscious examination or observation by a subject of his or her own conscious mental process.” (Lyans, 2006: 2874). Moreover, introspection is essential to be in conscious because to access our own stream of conscious is possible by means of introspection. For example, to introspect the pain in the teeth is related to give an attention to the teeth in order to say how it feels. Moreover, memory requires introspection, since it is possible to mention neither self-awareness nor remembering. Since, while storing and remembering, humans have to be in the state of consciousness.

Secondly, episodic memory is also context-depended system whereas semantic memory does not depend on the context.

> Episodic memory is particularly rich form of memory, which typically includes information about the events that comprise the episode, the people and objects that were present, the place or context in which the episode occurred, and temporal information that provides a sense of chronology (Smith and Mizumori, 2006: 716).

Remembering an event in episodic memory exists in the context. There are various experiments related to remembering or learning a subject related to episodic memory. The information in episodic memory can be used by means of the specific context such as spatial and novel contexts.

For instance,

> On the assumption that reconsolidation underlies the malleability of memory; we recently asked whether reactivation is involved in the updating of human episodic memory” (Hupbach et al. 2007). Subjects learned a set of objects in session 1. Forty-eight hours later (session 2), subjects were either reminded of the first session or not and immediately afterward learned a second set of objects. Again 48 h later (session 3), subjects were asked to recall the first set only, that is, the objects learned in session 1.Reminded subjects showed a high number of intrusions from set 2 when recalling set 1 in session 3, while subjects who had not been reminded showed almost no intrusions, demonstrating that the updating of pre-existing memory is dependent on reactivation of that memory (Hupbach, Hadt, Gomez, and Nadel, 2015: 574)

The experiments related to this assumption were explained in the same article[18]. In Psychology, similar assumptions are generally given to make a related experiment about the relation between memory and learning, remembering.

Thirdly, the same information does not enter into episodic memory twice. Since, the information in episodic memory consists of remembered past, personal experiences in specific time and place. In other words, episodic memory consists of the personal past experiences so all information stored with experiences are not same. Each experience supports to store different information in episodic memory. For example, suppose that you had traveled to Berlin twice. The information about the first trip stored in episodic memory is not as similar as the stored information related to the second trip because you had different experiences and memories about each of them. Also, it is impossible to be able to neither live the past nor experience the same situation again. Every time, a person experiences different things. For instance, a student has different experiences in each day in school.

Furthermore, episodic memory differs from semantic memory in terms of the capacity. 'The capacity' means the types of information that semantic and episodic memories collect; at the same time, the capacity is about how support to human cognition by episodic and semantic memories. Episodic memory recollects individual specific past events; for instance, meeting the most famous actor in April 2014. "The essence of this type of memory is its specificity, its capacity to represent a specific event and to locate it in time and space" (Baddeley 2001: 1346). Nonetheless, semantic memory collects the general information about the world. Thus, it does not include the aspect of space and time. 'Germany is a member of the European union' is an instance of general knowledge. Episodic memory is a system, which can keep the temporal order of personal events, but semantic memory does not have such capability. Therefore,

[18] The article is '*the dynamics of memory: Context-dependent updating* written by Hupbach, Hadt, Gomez, and Nadel in 2015. The detailed information about experiment can be found at page 575 in the article.

episodic memory has capacity to make 'mental time travel' allowing people to travel into back and future by means of collecting specific experiences. For example, you might remember talking with your mother yesterday and planning to go shopping tomorrow afternoon. This situation will travel forward in time to plan your day. Moreover, episodic memory has the capacity to remember specific events, unlike semantic memory. To illustrate, I remember that I received a black belt in Taekwondo in May 22, 2013. According to Tulving, "The time is not a calendar time but the rememberer's personally experienced time" (1983: 39). It is possible to remember the events in calendar time as showed in the example since remembering the calendar time of the specific events is also related to personal specific awareness on the events.

The other capacity of episodic memory is supporting to learn from past experiences. However, semantic memory supports us in analyzing the situations. Learning from the past is not the content of semantic memory. For example, analyzing the present data learns the economy of Turkey. As a result, episodic memory is a system, which is related to particular, personal and more specific information while semantic memory is based on more general and easily accessible information. The distinction between episodic memory and semantic memory is going to be analyzed based on auto-noetic in the next part of this thesis.

3.1.3. Differences based on Auto-noetic

There is a distinction between episodic and semantic memory in terms of 'consciousness' to which they are related. Memory is one of the crucial aspects in order to be conscious. For, remembering is related to memory and remembering requires a conscious. According to Tulving,

> One might think that memory should have something to do with remembering, and remembering is a conscious experience. To remember an event means to be consciously aware now of something that happened on an earlier occasion (1985: 1).

Consciousness has been scientifically worked in recent years. There are various definitions of consciousness. Nevertheless, it simply means awareness of something such as time, experiences, self. In addition, it is classified in different types such as anoetic, noetic and auto-noetic. Tulving describes three types of consciousness namely anoetic, noetic and auto-noetic (1985: 1).

These three types of consciousness are defined as knowing consciousness. According to Vandekerckhove and Panksepp, “auto-noetic and noetic consciousness that are the higher levels of knowing and awareness based on episodic memory and semantic memory” (2009: 1018). Therefore, episodic memory is defined by ‘auto-noetic (self-knowing) consciousness’ whereas semantic memory is defined by ‘noetic (knowing) consciousness’. Auto-noetic consciousness simply means awareness of personal time, in contrast; noetic consciousness means awareness of the world. According to Tulving “Noetic consciousness allows an organism to be aware of and to cognitively operate on objects and events and relations among objects and events in the absence of these objects and events” (1985: 3). On the other hand, Holland and Smulders mentioned another aspect of consciousness: “auto-noetic consciousness: part and parcel of human episodic memory is the subjective experience of travelling back in time and re-experiencing the memory in the awareness that this is something that happened to you personally in the past” (Tulving, 2001). Furthermore, auto-noetic consciousness can be called as self-knowing or self-awareness. Auto-noetic consciousness is crucial for episodic memory. Holland’s and Smulders claimed “self- consciousness ties to the experiences of episodic memory” (2010: 102). Hence, this type of consciousness supports not only awareness of subjective time but also mental time travel, which is provided by episodic memory not like the other kinds of memory.

Mental time travel, through subjective time, allows people to go backward into their personal past and forward into their personal future by the means of auto-noetic consciousness. Also, only episodic memory can allow the individual to mentally travel through their subjective time including the past and the future.

Why the auto-noetic consciousness is related to mental time travel is that it allows the individual to think about the future and travel back in time. In light of these views, episodic memory needs a conscious awareness to remember the past and image the future. At the same time, Tulving claimed that 'no auto-noetic, no mental time travels' (2002: 2). Due to the fact that remembering and storing the episodes without auto-noetic awareness relating to the past and future is possible, "auto-noetic consciousness is a necessary component of remembering" (Tulving, 1985: 5).

When we look at the capacity of semantic memory in terms of consciousness, we find no such necessity for semantic memory, due to the fact that semantic memory is not related to 'remembering' but it is related to 'knowing'. Later, the distinction between two memories in terms of the functions is going to be given chapter and verse. Therefore, semantic memory is based on noetic consciousness, owing to the fact that noetic consciousness is related to retrieval of impersonal factual information. In addition to that, episodic memory is based on auto-noetic consciousness because of containing the awareness of personal time, in contrast; semantic memory based on noetic consciousness, which does not contain personal time awareness. In conclusion, it is quite clear that the two types of memory, episodic and semantic memory, differ from each other in terms of consciousness on which they are based.

In the next section, the distinction between episodic and semantic memory is analyzed in terms of their functions.

3.1.4. Functional Distinction

Episodic memory is different from semantic memory in terms of its function. Nonetheless, the functional distinction is not parallel with that Tulving did in his book, *Elements of Episodic Memory*. Tulving distinguished episodic and semantic memory in terms of whether they are repeatable or non-repeatable system in function. However, in this part, the function is used in a different sense.

The function of episodic memory is 'remembering' while the function of semantic memory is 'knowing'.

Firstly, why episodic memory is related to remembering is to involve thinking of the events occurring in earlier time. In other words, episodic memory is the only system that is past-oriented, so it supports to think 'back', i.e., previous or subjectively past experiences. According to Norman, "episodic memory refers to our ability to remember specific previously experienced events: we can recall previously experienced events and we can recognize a stimulus as having been encountered previously" (2006: 3544). For example, a person sees a codger with green dress in the street tonight while walking, and tomorrow when he sees something, which is green, he remembers the codger who he saw before.

Secondly, episodic remembering always requires an agent as a rememberer, an actor or as an observer of the event. Since, the agent is the necessary and sufficient component to encode retrieval and recollect and so on. At least, one observer must be there to remember. In other words, episodic remembering requires an active agent**.**

Thirdly, retrieval from episodic memory is concerned with 'www criteria'. Tulving (1972) said, "Remembering what happened, where and when was the part of the original definition of episodic memory in human" (Holland and Smulders 2010: 96). When the question 'what did you do last night? ' is asked, the person remembers the related information by means of episodic memory. In a word, he gets the information from episodic memory. For example, if the police officer asks 'Where were you last Friday at 12:00 pm?' to the lawbreaker, he remembers that he was at Blue Cafe last Friday at 12:00 pm by means of stored information in episodic memory. Tulving said that "people use the word remember when referring to personal recollection" (1984: 223).

Fourthly, episodic remembering is also related to remembering of word list. In other words, a word list is prepared by the experimenter to show the participants for sufficient time. After that, how many words they remember, or whether they remember the words from the list or knowing it from somewhere is asked to the participants. Actually, these experiments are usually made to analyze the distinction between 'remembering' and 'knowing', yet almost is related to remembering so related to episodic memory.

Finally, remembering consists of all perceptual aspects such as seeing, hearing, taste, smell, feeling and cognitive aspects such as thought, observing on account of the fact that everything related to the events is recollected by the agent while remembering. However, semantic memory is not interested in 'remembering'. Since, semantic memory is present- oriented system so it is concerned with 'now' not 'past'. According to Baddeley, "semantic memory reflects our knowledge of the world: knowing the meaning of world bottle" (2001: 1346). Therefore, it is related to the question, 'What is semantic memory?' For example, when someone asks you what the piano is, the idea of piano makes some sense for you but you do not remember the specific event related to the concept of the piano. At the same time, semantic memory is generally concerned with 'yes or no' questions.

The other difference is that remembering is interested in recollection whereas knowing is based on familiarity. In other words, recollected events, experiences are the most important components of the 'remembering', but for knowing, the familiarity is significant. Therefore, remembering is based on episodic memory, in contrast; semantic memory is based on knowing by virtue of their definitions. Moreover, the distinction between episodic and semantic memory in terms of consciousness is related to their function. In other words, auto-noetic consciousness supports remembering since it requires conscious awareness. Also, while remembering the events, which are consciously stored in memory, are used. "Episodic and autobiographical recollection involves re-experiencing a past event that is specific in time and place" (Ryan, Hoscheidt and Nadel, 2008: 5). Moreover, it is possible to mention about semantic recollection concerned with facts and general knowledge about the world but it is not the same as episodic recollection or re-experiencing. Since, it does not involve thinking of past events or special events occurring in special time and the particular place, however; it involves actualized knowledge. “Semantic recollection has to do with knowledge as it is factual and typically devoid of emotion or reference to time” (Ryan, Hoscheidt and Nadel 2008: 5). In addition, Fernandez shows that for any subject S and proposition p, if S remembers that p, then:

> For episodic memory, S episodically remembers that p if S would now remember that p even if she had never believed that p before. On the contrary,
>
> For semantic memory, S semantically remembers that p if, she not believed that p sometime in the past, S would not remember that p now. (2006: 50).

Therefore, only it is related to ‘knowing’ related to thinking about the situations in the world by virtue of noetic consciousness or knowing awareness. For example, if ‘what is the result of two plus two?’ is asked, the result 4 is known not remembered.

The other function is that only episodic memory has is to imagine the future. As already mentioned, episodic memory allows mental time travel by virtue of auto-noetic consciousness. Mental time travel supports the person to think or re-experience the past events but also to imagine future events. In a word, while making future plans, remembering the past event has a crucial role. For example, whenever a person remembers their last birthday party and mentally re-experiences the good memories during the party, the person can also imagine a future birthday party by considering the good effects of their last birthday party. While Eacott and Easton are claiming that “such planning depends on mentally experiencing the possible future scenario” (2012: 200), Tulving (1998) claims that “re-experiencing the past events with initial episode is important not only to think our past but also predict or plan the future” (Baddeley 2001: 1345). However, semantic memory is related to neither thinking past nor future imagining. It only supports the species, humans and non-humans, to know and use their knowledge for present purposes because of the fact that it is not necessary to re-experiencing the facts, objects or so on. For example, it is to know that the new year starts at January 1.

Finally, it is quite apparent that remembering is more important than knowing according to Tulving. He claimed that "remembering one's past is a different and perhaps more advanced achievement of the brain than simply knowing about it" (1989: 361). In the light of these views of this quotation, it can be obvious that episodic memory and episodic remembering are significant for human cognition. To conclude, it is indisputable to say that there is a huge distinction between episodic and semantic memory in terms of their functions.

3.1.5. The Application Distinction

There is a distinction between the implementation of semantic and episodic memories in a computer. The issues start with a question, whether a computer with episodic memory is possible or not. The main difference is that episodic memory is about remembering persons' own past experiences while semantic memory is about knowing general facts and ideas. Therefore, it is difficult to implement episodic memory into the machines rather than semantic memory because the machine does not have its own experiences instead of having their own symbols. Even if its own personal experience such as visiting the most important place in the world was held in the machine, it only talks about the world by manipulating the algorithms. It never talks about its own original experiences, personal identity and the process in its subjective time. For example, when you ask a computer something about their trip to Italy, it can give a good answer to the question but it cannot act like humans because of giving the answers by using only their symbols. Machines do not store their own perceptual and personal experiences, but only can manipulate symbols and algorithms from their experiences. For example, it does not have the ability to taste or smell anything. Remembering past experiences requires consciousness, however; the machine consciousness is related only to the symbols. It does not have the ability of self-regulating or self-awareness.

Nonetheless, it is easier to implement semantic memory rather than episodic memory owing to the fact that semantic memory in the machine is as similar as semantic memory in humans. It can semantically act like human beings. Furthermore, it is able to get general knowledge about the world, and use the language as human language so that it can make a conversation with a human and it plays the games requiring thinking as chess.

As a result, it can be said that the computer with semantic memory is more possible than the computer with episodic memory. It is easy and acceptable to implement semantic memory into the machine. However, it does not mean that episodic memory is not important for the machine. Actually, it is more significant than semantic memory. For,

> Psychologists and AI researchers realized that semantic networks did not account for all the data. First, not all knowledge is in small, static chunks. Memories are variable in size and malleable in content. For example, the memory of what I had for lunch today might vary from nothing to a seven-course meal. Second, the semantic network theory does not explain how knowledge is incorporated into memory (Slade, 1991: 43).

Therefore, episodic memory is necessary for AI. To solve problems and adapt into environment requires the past episodes. It is not completely possible according to the researches since the agent with episodic memory does not have all capabilities supported by episodic memory as human beings. It is necessary to make researches to develop episodic memory in the architectures. Langley, Laird and Rogers claim that

> The focus on problem solving and procedural skills has drawn attention away from episodic knowledge. We need more research on architectures that directly support both episodic memory and reflective processes that operate on the structures it contain (2009: 15).

Episodic memory in Soar is going to be explained on the ground of episodic memory in the Soar Cognitive Architecture. The aim of further chapter is to understand whether episodic memory in Soar can be accepted as episodic memory according to the specialties of episodic memory given in the previous chapter. Since, episodic memory in Soar is not totally similar as episodic memory in human. According to Rosenbloom, Laird and Newell,

> This architecture then forms the basis for wide-ranging investigations into basic intelligent capabilities- such as problem solving, planning, learning, knowledge representation, natural language, perception, and robotics- as well as applications in the areas of expert systems, and psychological modeling (1993: 1).

An agent with episodic memory has only some capabilities supported by episodic memory. Therefore, does an intelligent architecture really have episodic memory? The question is the main point. In a word, how we decide that memory in an agent is episodic memory. Is sufficient having some basic high-level cognitive capabilities to have episodic memory? This is the controversial issue.

CHAPTER 4

MEMORY MODEL

4.1. The Agent with Memory

Memory is one of the most crucial components of human cognition as well as Artificial Intelligence, cognitive architecture. Human beings and these systems need to use their own past experiences so that they are able to properly act in their present and future life. Therefore, experience is essential for building an agentive system. Memory has three main functions, encoding, storage and retrieval. Nonetheless, experience plays an essential role during these functions in memory. In the early period of Artificial Intelligence, especially computers, memory was thought as 'storage'. Additionally, Von Neumann is the first figure to work on developing the idea of the storage program. However, this thought has changed during time by means of development in technology.

Memory is used not only for the capability of storing but also for other cognitive capabilities. Since, the emergence of Artificial Intelligence or cognitive architecture is based on what humans do so that they are designed according to humans' cognition as well as cognitive abilities. During time, memory in these systems has been considered as an essential tool for building some high level cognitive capabilities such as learning, sensing, reasoning, decision-making, and problem-solving and so on. Generally, semantic memory is implemented into Artificial Intelligence rather episodic memory because knowing semantic information is easy for humans as well as computers even if episodic memory is important for all phases. There are essential examples of the machine systems which have semantic memory such as; General Problem Solver by Newell and Simon to be able to solve the problem like humans, Dendral by Simon's student who is Edward Feigenbaum to analyze organic compound and Shardlu with the number of actions by Terry Winograd to be able to answer questions. Soar also has semantic memory, however; episodic memory is the main issue of the chapter and episodic memory is accepted for only human beings so that it is hard to add episodic memory in the architectural systems. Moreover, “one of the primary challenges for cognitive structure is coordinating the many capabilities we associate with intelligent systems such as perception, reasoning, planning, language processing and learning” (Laird 2012: 6). In spite of the fact that there are the engineering problem of building the episodic memory and the research problem of investigating its effectiveness, there are limited examples of implementation of episodic memory for Artificial Intelligence. It is necessary to discuss whether the memory in these AI is episodic memory or not. These examples of AI support some high-level cognitive capabilities as perception. They do not have all capabilities related to episodic memory as humans. Additionally, they have essential role in development of Artificial Intelligence although they are related to only one of the properties of episodic memory. However, it is not possible to mention about all examples relating to the implementation of episodic memory; so giving some important example is helpful to improve the perspective on the implementation.

Firstly, ACT-R and Epic are two examples for the implementation of episodic memory even though they have task-independence architectural episodic memory system. Secondly, the other is ‘basic agent’ created by Vere and Bicmore in 1990 with only primitive episodic memory capability, which is to answer the questions. Thirdly, Lida structured by Franklin and Patterson in 2006 with a few details of episodic memory as Clarion by Sun in 2006.The fourth is “Icarus (Stracuzzi et al 2009) recently added the ability to associate temporal ranges with concepts, but their approach does not directly support the retrieval of complete episodes; rather it focuses on retrieving individual concepts, which makes it more similar to semantic memory with time stamps” (Nuxoll and Derbinsky 2012: 226).

In addition to these mentioned systems, there are case-based reasoning systems, which are based on episodic memory. These mentioned that Kolodner described systems in 1993. A case-based reasoning system is able to find a solution to retrieved problem and adapts it to a new one by means of a case in the system. Furthermore, they are designed for a specific task; so they are not general systems because of the fact that like all systems, case-based system are designed according to some aspects in human intelligence. One of the most important architectures is the Soar Cognitive Architecture, the main architecture mentioned in this section.

Before analyzing episodic memory in Soar, it can be suitable to mention the importance of episodic memory for cognitive architecture. At the same time, it is necessary to generally give information about Soar's memory system. As mentioned in the previous chapter, episodic memory is related to 'person's own history'. Having personal past experiences and knowledge support some high level cognitive capabilities. According to Nuxoll, "various cognitive capabilities such as sensing, reasoning and learning are easily performed by the means of knowing personal history" (2007: 1). Therefore, it is quite obvious that sensing, reasoning and learning are the most significant capabilities facilitated by episodic memory. Also, they are high-level cognitive capabilities relating to episodic memory. Episodic memory is able to make contribution to prove the capabilities of the cognitive architecture.

The main contribution is facilitating to predict behavior and environment by virtue of temporal structure. It concerns with retrieving the episode in accordance with their order. Episodic memory facilitates some cognitive capabilities in Artificial Intelligence. Laird, Nuxoll and Derbinsky claimed that "at abstract level, episodic memory provides a memory of previous events and supports additional cognitive capabilities that enhance the reasoning and learning capabilities of an integrated intelligent agent" (2012: 225). An agent can answer questions about the past by means of episodic memory. Additionally, it helps the agent to improve its reasoning about the current situation by the immediate perception coming from the environment. The third contribution is that possible situations relating to actions can be gotten with episodic memory. Therefore, some computers are good at playing chess because of having unlimited possibilities. Episodic memory is related to imagining future so that an agent is able to use its knowledge concerning the results of its past action to predict and influence its future actions.

In light of these views mentioned, Laird, Nuxoll and Derbinksy analyze the implementation of episodic memory into Soar especial section in their book, *The Soar Cognitive Architecture* in 2012. John E. Laird analyzed the Soar Cognitive Architecture in 14 chapters in 2012. The book has three main goals. The primary aim of the book is to support the description of the Soar on the ground of how it works and why it is designed. The second goal is to support the definition of a cognitive architecture. The final goal is to be able to support human-level agent by evaluating Soar as a cognitive architecture.

Before analyzing episodic memory in Soar, it is useful to look at Soar memory systems and their functions. Due to the fact that Soar is related to which components are essential for supporting human-level intelligence, Soar has been developing for a long time by adding more capabilities. There are the main structures that Soar has so as to make computation. These structures are goals, problem spaces, states and operators. While each of the states represents a situation, an operator makes changes in the situation. Additionally, Soar has all memory systems as humans. Long-term and short-term memories are implemented into Soar. Therefore, the five subcomponents, which are semantic, episodic, procedural, perceptual and working memory, are added into it. There is a relation between all systems. The process starts with perception.

Firstly, perception called as input enters into perceptual short-term memory, and then it is stored in Soar's working memory. It works to retrieve the knowledge from Soar's long-term memories, at the same time; it bases on initiating action. Moreover, Soar's long-term memories are independent from each other because of associating with different learning mechanisms. According to Laird, “procedural long-term memory is responsible for retrieving the knowledge that controls the processing” (2012: 18). The information in these memory systems is defined as production rules to make matching with the structure in working memory and act in parallel way. Production rules are able to make arrangement in working memory.

According to Derbinsky, Li, and Laird, “procedural knowledge is represented as if-then rules: the conditions test patterns in working memory and the action add and/or remove working memory structures” (2012: 194). In addition, they generate the preference, which is used by a decision procedure. Decision procedure in Soar means to select an operator since they are the basis of decision-making and actions in Soar. Therefore, an operator is the cause of non-temporal changes in working memory.

Moreover, procedural memory is related to the knowledge of the agent about when and how the actions are performed. Procedural long-term memory is with reinforcement and chunking that are learning systems in Soar and so they have different functions. Chunking that is single learning system concerns with learning new production rules whereas reinforcement learning is related to the rules creating with preference for operator selection. Working memory is the main part of the Soar’s memory systems owing to the fact that it is worked by the other memory systems and process so that it can easily retrieve from semantic and episodic memory or the environment. Moreover, the current states are symbolically kept into working memory. These current states include perception, retrievals from long-term memory, goals and so on. In addition, semantic memory is similar to human semantic memory. It is memory for storing general facts. Nevertheless, episodic memory differs from humans’ episodic memory because it is memory to store snapshots of working memory. It is accepted as episodic memory by means of having some high- level cognitive capabilities such as learning. That is problem to accept memory in Soar as episodic memory. How we decide is a hard question that is necessary to be discussed. Moreover, semantic memory is with semantic learning mechanism whereas episodic memory is with episodic learning. Both of these types of memory systems have their common specialty. They both have memories, which are retrieved from the working memory by means of the cue constructed in working memory.

After this information, it is quite apparent that there is one goal related to all memory systems. The goal is generating the behavior. While procedural memory supports the control mechanism, working memory is the common workspace. The functions of episodic memory are going to be mentioned in separated parts. In addition, Laird claimed, “working memory, the decision procedure, procedural memory and chunking are the original parts of Soar” (2012: 19). These properties are not only taken into consideration in Soar but also in other cognitive architectures. For all architectures, the stored knowledge is kept in long-term memory and retrieval of that knowledge makes from working memory. Moreover, learning is the most important cognitive ability of human intelligence and it is supported by memory. Therefore, long-term memory systems in Soar are associated with learning mechanism. To begin with, procedural memory is associated with two different learning mechanisms. Procedural memory is associated with chunking. The source of knowledge in Soar is traces of rule firings (in computers) in substrates while the representation of knowledge is production rules. Furthermore, matching rule conditions occurs retrieval and so the agent is able to retrieve actions by means of procedural memory. Reinforcement learning is the second learning mechanism relating to procedural memory. The source of knowledge in that learning mechanism is reward and numeric preferences whereas the representation of knowledge is shown by numeric preference in rules. In addition to that the retrieval of knowledge is as same as procedural memory via chunking.

Secondly, the learning mechanism of semantic memory is semantic learning. In this mechanism, knowledge is taken from working memory. Knowledge is represented as a mirror of working memory objects structures. Retrieval of knowledge requires matching cue and the objects, which are retrieval rather than the actions.

Thirdly, episodic learning is the learning mechanism of episodic memory. Episodic memory also gets knowledge from working memory as similar as semantic memory. The representation of knowledge is episodes that are snapshots of working memory. Retrieval exists by virtue of partially matching cues and episodes, which are retrievable instead of the objects or actions.

Finally, the source of knowledge in perceptual memory is perceptual short-term memory. The representation of knowledge occurs with quantitative spatial and visual depictions. The retrieval of knowledge is deliberately recalling based on symbolic referent. Laird showed these types of memories and learning systems taking in the Soar in the table (2012: 20). In light of these views mentioned in Soar, retrieval of the knowledge is generally based on exact matching of cues in working memory from the long-term memories (semantic and episodic). As a result, it can be said that the agent can store more amount of knowledge over long time and it properly acts in real life by the virtue of long-term memories. After the general view of memory system in Soar, the important long-term memory system in human intelligence, episodic memory, as well as Soar, is going to be explained on the ground of how it is implemented into Soar.

4.2. Episodic Memory in Soar

Episodic memory in Soar was designed according to the common functions of episodic memory in humans. These common functions, defined by Nuxoll and Laird (2004, 2007), are "an automatic, architectural symbolic memory that supports cue-based retrieval" and "autobiographical representation of the agent's moment-to-moment experiences" (Laird, Nuxoll and Derbinsky 2012: 227). Therefore, they aimed to add only the most important functions of episodic memory in human into Soar rather than all functions.

Generally, episodic memory and working memory in Soar interact with each other in a direct way. When an episode is stored, this episode becomes the elements of working memory. Moreover, an episode carries temporal information so that retrieving the episode at once easily accesses the past and new episodes**.** The information in working memory is encoded in episodic memory by means of episodic-storage model. Also, there are cues constructed by an agent into working memory so that it is possible to retrieve episode by the agent. The processing of retrieval is going to be later mentioned in details. Furthermore, according to Laird, Nuxoll and Derbinsky,

> episodic memory includes the past experiences, which are related to the properties of places that have already been visited, used and applied operators and produced results. Furthermore, episodic memory is about the usage of the information about the past for decision-making and action in the present situation (2012: 229).

Episodic memory is implemented into Soar in terms of the stage of its operations, encoding, storage, retrieval, and the use of episodic memory including perception, reasoning, and learning. Firstly, encoding and storage of episodic memory are going to be explained. Secondly, retrieval in episodic memory of Soar is going to be analyzed. Then, the usage of episodic memory shall be taken into consideration in terms of perception, reasoning and learning. Nuxoll and Laird claimed that encoding; storing and retrieving are the three stages of learning mechanism in cognitive architecture. These stages are also related to episodic memory. Moreover, episodic memory is defined as the simplest learning mechanism since it is only concerned with the current situation. Nonetheless, episodic memory in Soar differs from the other episodic memories in terms of encoding, storing and retrieval.

Firstly, encoding in Soar is related to recording only changes in working memory so an episode is different from the previous and the next episode on account of the fact that the added or removed episode in working memory is only stored rather than recording complex elements. Moreover, episodic memory automatically stores the agent's own experiences on the ground of encoding initiation, episode determination and feature selection; therefore, there is a transition between episodes. Episodic initiation is related to the encoding time of episode. In Soar, encoding time and the agent's time are parallel. Episode determination concerns in the content of an episode. In Soar, the content of episode is consisted in perception, motor commands and internal data structures. Feature selection is related to selecting to match the subset of features in episodic memory during retrieval. According to that view, there are two approaches supported by Soar. The first approach is the correspondence of an episode and this episode has only one single processing cycle. Therefore, the changes are recorded at the time when the processing cycle finishes. These changes are not related to the ones between the agent's actions rather they are related to the agent and environment. Soar only stores the agent's action occurred by external factors episode structure and episode dynamics. The structure of episodic memory affects on storage and retrieval. Also, episodic dynamic is related to whether the content of episodic memory is changeable over time by forgetting or generalizations. According to Nuxoll and Laird, episodic memory is static in their systems. There is no forgetting or reorganization. The second approach is related to an episode in which working memory element is stored. The element takes place in top-level stage including perception and the agent awareness for situation concerning with episodic memory so that Soar is able to store the information. Hence, neither the low-level states nor information from episodic memory can be stored by it because of the fact that "storing sub-states greatly increases the amount of data stored and complicates the storage and retrieval process" (Laird, Nuxoll and Derbinksy 2012: 230). However, unless Soar stores information from episodic memory, some memories may be lost. These memories may be lost due to the fact that some significant capabilities which cannot be implemented into Soar. This shows that episodic memory is not good at Artificial Intelligence as it is in humans.

The second stage related to episodic memory is retrieval. It consists of five components such as retrieval initiation, cue determination, retrieval, retrieved episode representation, and retrieval meta-data. The retrieval initiation is related to the time of retrieval. In Soar, whenever the agent has a cue, retrieval is initiated. Cue determination concerns with specifying of the cue. In Soar, the cue shows existing and non-existing things in retrieved episode. Retrieval is based on which episode is retrieved when a cue is occurred. In Soar, the matching is used. In addition, retrieved episode representation is related to the representation of a retrieved episode in the agent. Retrieval meta-data is related to whether there is meta-data about the episode and its cue. Moreover, there are two types of retrieval that are available in Soar. These two retrieval's types are based on a cue. The first type of retrieval is related to a cue gotten from working memory elements to be matched with the stored episode. The second type of retrieval can be thought as a follow-up the first one. The stored episode is retrieved by the means of a cue so that the retrieved episode is used to create a structure on the state. After retrieving an episode, it is accessible to retrieve next and previous episode. According to the writers, "this type of retrieval allows the agent to move forward (or backward), re-experiencing episodes in the order in which they occurred or in reserve order" (Laird, Nuxoll and Derbinsky 2012: 230).

In Soar, retrieval occurs by virtue of an operator. The agent selects an operator creating a cue and being able to use next or previous command. The cue for episodic memory, which is necessary for retrieval, is related to working memory in Soar. Additionally, the complete state in Soar can be used as a cue so that an agent is able to recall a similar situation with the current. Consequently, Soar concerns with best matching cues by the episode since it is significant component of retrieval for episodic memory. Whenever the episode makes best- matching in the cue, the cue is returned by means of matches made by the recent episode. However it is not always possible to retrieval since it is possible to specify unretrieved particular episodes by the means of a cue. Thus, the agent is able to properly act by eliminating used episodes.

The best-matching episode is used in working memory. In a sense, "once the best-matching episode has been found, it is reconstructed in working memory" (Laird 2012: 231). Although best matching is essential for retrieval, it is possible to find failed retrieval. That means episodes cannot sometimes make matching with anything so that failed retrieval can be observed. Moreover, the exact best-matching is generally necessary for the agent to retrieval but sometimes it can be beneficial to use partial matching. The usage of which matching is proper based on the agent. Why episodic retrieval is important for Soar is that the previously retrieved states are stored in episodic memory, so that the agent can use them to learn new states. After explaining the stages of episodic memory in Soar, the cognitive capabilities supported by episodic memory are explained in 'The Soar Cognitive Architecture'.

4.3. Cognitive Capabilities in Soar

There are three important cognitive capabilities, which are included in it. The first one is 'perception', the second is 'reasoning' and the third one is 'learning'. To begin with, it is useful to mention about what perception is. Perception means being aware of things occurring in the environment by the means of senses such as seeing, hearing, smell, touch and taste. Perception relating to each of them occurs in process. The perceptual processing is supported by episodic memory as well as situational awareness. By means of the supporting of episodic memory, the agent can make a relation between previously perceived data in similar situation and the current perception in states. Perception is divided into three parts in Soar by Laird, Nuxoll and Derbinsky (2012) as noticing familiar or novel situations, detecting repetition and virtual sensing. Laird, Nuxoll and Derbinsky claimed "episodic memory can provide a basis for determining novelty by using the current situation as a cue for retrieval" (2012: 232). Hence, the agent is able to make a distinction between the current situation and the retrieved memory in terms of similarities and differences when retrieval is the successor.

When we look at detecting repetition, we can say that episodic memory is important for Soar, actually all general intelligent agents**.** However, episodic memory in all general intelligent agents should be improved. The environment is deliberately or mistakenly explored by the agent, at the same time, it makes generalization of states. Therefore, it is possible to detect the familiar situations so that the agent tries to determine whether the current and earlier states are familiar with each other. Furthermore, the agent may mistakenly turn to the same place so that the agent can be adjusted by means of controlling knowledge to make no such repetition in the future states as well as the present situation by obeying the commands. Moreover, visual sensing is supported by episodic memory. Since, an agent has the ability to perceive the environment in two ways as spatially and temporally, and these spatio-temporal information are stored in episodic memory.

In addition to that "episodic memory allows that agent to use its memory to expand its perception to include what it has sensed in other locations and at other times, giving it effectively a much broader awareness of its situation outside of immediate perception" (Laird, Nuxoll and Derbinsky 2012: 233). Thus, some questions relating to particular space and time can be answered by means of episodic memory. For example, the question the agent should easily answer "Where is the nearest restaurant?" since it is related to semantic memory. That is a fact. Also, the agent can make a decision about the present situation by thinking through past and exact knowledge by virtue of episodic memory. The agent is able to decide what it should do when it goes to same restaurant at other time by means of episodic memory. Additionally, the agent with episodic memory can pick out the changes in the environment relative to its actions. For example, once an agent perceives an object in its environment, it always retrieves that object even if it does not exist in there. When the agent is asked where the object is, it retrieves the objects with knowledge from past experience in episodic memory. That can be seen as deficiency but it is not due to the fact that the agent can learn new states, although it uses wrong or not proper cue in order to access the goal. Additionally, the agent is able to manage long-term goals by means of episodic memory. That is related to the retrieval of non-active past goals at the time when it is necessary to be active in the current situations. In light of these views above, the high level cognitive capability that is 'perception' is emerged in the general intelligent agent as Soar by adding episodic memory into it.

Secondly, the other high-level cognitive capability in Soar supported by episodic memory is 'reasoning'. Reasoning requires the agent's own history to predict the future actions and to explain the past action. Therefore, episodic memory is related to reasoning since only episodic memory stores the past events or information from the personal history. Also, reasoning is analyzed in terms of four parts as (1) action modeling and environmental dynamic, (2) remembering previous successes and failures, (3) explaining behavior, and (4) prospective memory.

Firstly, action modeling and environmental dynamics are related to episodic memory. Achieving its goal is essential for all agents. To achieve the goal, it is useful to know the influence of the environment on action so that the agent is able to select proper action, and a proper action is selected from episodic memory. Moreover, reasoning gives change to the agent to be able to predict the changes in the environment. Therefore, the agent can predict the immediate changes in the environment result from retrieved action similar with its past action by the means of providing of episodic memory. After retrieving the immediate states, the results of that action can be easily recalled so that the agent can find more informative result by continually performing. Also, the important point is that retrieving is a function supported by episodic memory. Thus, action modeling requires episodic memory.

Secondly, remembering previous success and failure is helpful to provide the agent's reasoning and learning. Since, the agent can predict the changes in the states by remembering it's own success and failures. Also, action modeling is increased by means of retrieval. Since, the agent can adapt the changes in the state into its own goal. In other words, the agent can make a relation between the changes in its environment and its goal. That is related to temporal contiguity. It is natural for them to be changes in the environment. Also, these changes influence to their agent states, from episode to episode so that the changes will affect over all states. To adjust the environment, episodic memory is essentially important for the agent because remembering failure and success require episodic retrieval and memory.

Thirdly, the agent can explain its behavior by virtue of its episodic memory. Since, remembering the past action helps the agent to make a relation between its current and its past actions. Explaining behavior means giving answer to the question such as why was it was done? Or what was done? Chi and Vanlehn said "explanations are useful in teaching others, but also for learning from your own success and mistakes, such as during a debriefing session or in self-explanation" (Laird, Nuxoll and Derbinsky 2012: 234). Additionally, problem solving is related to episodic memory since the agent can retrieve the solution of the problem by using its own episodic memory.

Fourthly, prospective memory is also explained in the scope of reasoning because of relating to remembering an action. The agent can make future plans by using episodic memory. Since, episodic memory helps the agent to arrange its future plan by storing the information relating to future goals. For example, while coming back to home from school, the decision of stopping in their bakery so the memory work on to achieve the goal. In light of these parts explained on the scope of reasoning, it is quite clear that these parts concern with each other. Action modeling is improved by the means of remembering previous success and failures. Also explaining behavior requires learning from remembering previous success and failures.

Finally, the other essential high-level cognitive capability in Soar supported by episodic memory is 'learning'. Learning requires sufficient time so episodic memory provides learning in agents owing to the fact that episodic memory stores previous experiences of the agent to be able to use them whenever they are necessary. Furthermore, according to Laird (2012) episodic memory is defined as a learning-mechanism, and so episodic memory supports the retroactive learning. It means that while the agent is performing, it does not generally learn all necessary and specific information in real time. However, episodic memory stores all essential information so that the agent is able to use these information, which have to been learned when the proper time is accessed. As a result, when we look at these high level cognitive capabilities supported by episodic memory, it can be said that episodic memory is essential for general intelligent agent as well as Soar.

The Soar Cognitive architecture is the most important architecture for supporting these high-level cognitive capabilities by means of adding episodic memory. Not only these capabilities but also some other important capabilities are supported by episodic memory**.** Nevertheless, it is not possible to add all high-level capabilities supported by episodic memory in the architecture since episodic memory requires person's own experiences rather symbolic representation. Architectures cannot develop their own experiences because they work according to input/output rules, which are given. Therefore, it is questionable to say that this kind of memory system in Soar is episodic memory. To say that Soar has episodic memory as humans, it is necessary to know that episodic memory in general intelligent agent supports all cognitive capabilities in humans and they can have their own experiences. Thus, it is necessary to develop the ability of experience in the architectures in order to say that architectures are able to have episodic memory like humans do.

CHAPTER 5

CONCLUSION

Artificial Intelligence is one of the most important issues of philosophy owing to the fact that it is related to mind design[19]. Whatever is captured by mind is related to philosophy. Accordingly, the mind design is one of the most philosophical interests even though questions and answers about foundation of the field are still controversial in terms of ontological, technical and epistemological grounds. AI is in the scope of philosophy. Various (epistemological or ontological) works have been made in that time. In this work, the field of AI has been analyzed from the perspective of episodic memory**.** The aim of this study is to show whether AI is technically possible by virtue of memory. I argue that episodic memory is basis for all necessary condition for AI. In the thesis, I have tried to analyze the relation between episodic memory and the necessary components for AI, such as consciousness. I would say that the problem of consciousness can be also solved by adding episodic memory into AI, which is a good solution for all the problems of AI, If episodic memory is implemented into AI, all problems can be automatically solved. Thus, AI has been analyzed in terms of episodic memory.

The first chapter is the introduction about the review of the study. Firstly, the general information about memory, especially episodic memory, has been taken into consideration in this chapter. The organization of the study has been talked in the first chapter. Secondly, the information about AI has been given. Thirdly, how the relation between the memory and AI is has been analyzed. Fourthly, frame problem and introspection, which are two crucial problems in AI, and how these problems can be solved, are explained in the chapter.

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[19] "MIND DESIGN is the endeavor to understand mind (thinking, intellect) in the terms of its design (How it is built, how it works). It amounts, therefore, to a kind of cognitive psychology. But it is oriented more toward structure and mechanism than toward correlation or law, more toward the 'How' than the 'What' than its traditional empirical psychology" (Haugeland, 1997: 1).

In the second chapter, I have tried to give clearly ontological and historical background of AI on the ground of memory. To have the historical background of anything is helpful to understand the development of whatever is in the scope. The background from the birth of AI to Cognitive architecture has been analyzed in detail. When research the historical background, it is clear to say that the root of the thinking machine or AI has been formed Before Christ (B.C.). Moreover, it is obvious to see that the achievements and developments have increased during time. I can claim that the development of memory in AI is the most important part of the chapter. The main concern of the thesis is the role of episodic memory in AI. Therefore, in this chapter of the thesis, the achievements in AI have been analyzed in historical order in terms of various aspects such as expert systems, stored-programs and cognitive architectures.

In the third chapter, memory and memory systems have been talked in the terms of their own definition, their specific capabilities and their relations and interactions with each other. Episodic memory is one of the most important memory systems, which have been crucial point in the study. For this reason, there is a relation between episodic memory and some crucial high-level cognitive capabilities such as reasoning. Before analyzing the memory of AI, it is essential to understand human's memory since memory is one of the significant components to be intellect. Furthermore, memory is related to all cognitive capabilities in human mind or intelligence. Clearly, memory is defined as a container, which keeps all special and general information for humans to be able to exist consciously by remembering and using their stored information to get new information and also to make relations between the past and the present information. Thus, I have tried to give more information about memory in this chapter to be able to develop memory in AI on the bases of high-level cognitive capabilities.

In the fourth chapter, The Soar Cognitive Architecture, the most important cognitive architecture, has been in the scope due to the fact that cognitive architecture is another side of AI. The Soar Cognitive Architecture is more close to human mind by means of having episodic and semantic memory. Furthermore, it has some significant high-level cognitive capabilities, which are supported by episodic memory. The Soar Cognitive Architecture is one of the latest essential investigations in the field of AI. Not only human intelligence but also intelligence system requires a memory since, it supports and cognitive capabilities to be able to adapt into the environment.

Osman claimed that

> The very basic idea is to develop an intelligent system that must possess sensory and motor capabilities in order to predict and control the environment, and has some way of processing the information, which it receives in order to learn to adapt to changes in its environment (2010: 90).

Additionally, Soar has most of the cognitive capabilities such as reasoning and perception. Thus, I have tried to analyze memory, memory systems, and cognitive capabilities in the Soar Cognitive Architecture to be able to see the deficiencies of memory in AI and develop memory in AI in the further studies.

To conclude, I have tried to analyze the interaction between AI and memory on the basis of the high-level cognitive capabilities because of the fact that it is obviously necessary to analyze memory, especially episodic memory in AI in terms of philosophical interest. The claim is that memory has the significant role on human intelligence and Artificial Intelligence. If there is deficiency of memory in any intelligence systems, none of them properly acts. In a word, intelligence requires a memory to be accepted as 'intelligence'. Since, memory supports various crucial high level cognitive capabilities in human and any intelligence systems. Definitely, in my further studies, the deficiencies of memory in AI are actually going to be in the scope. Finally, the aim of the thesis is to demonstrate the importance of memory for the development of AI and solve the crucial problems in AI. It is necessary to make research to develop episodic memory in AI. If a proper memory model is supported to machines or intelligence systems, it is possible to increase high level cognitive capabilities in AI to the human intelligence level and to develop AI in terms of the high level cognitive capabilities. Adding episodic memory can be accepted as a certain solutions for the problems in AI. To make episodic memory as encompassing solution, we should firstly have an argument to be able to say whether memory in architectures can be cleary stated as episodic memory just as humans' episodic memory. Then, we would have a success to solve the problems of AI.

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APPENDICES

TURKISH SUMMARY

Felsefe, farklı birçok bilim dalının problemleri ile ilgilenen bilim felsefesi, zihin felsefesi gibi çeşitli alt dallara sahip bir disiplindir. Ayrıca, diğer bilim dalları ile iç içe olan nadir disiplinlerden biri olduğu da söylenebilir. Asırlardır birçok bilim dalının problemlerine değinerek problemlerin ne olduğunu çözümlemeye çalışmaktadır. Örneğin, felsefe psikoloji alanın sorunları ile yakından alakalıdır. Psikoloji nedir, hafıza (bellek) nedir, ve davranış nedir gibi sorularla ilgilenmektedir. Bellek, insanın edindiği bilgi ve deneyimlerin depolandığı yerdir. Fakat bellek sadece insanın bilgi, deneyim ve geçmiş yaşantısına dair olguları ve olayları depolamak değil, aynı zamanda depolanmış bilgiler sayesinde gelecek yaşantısına yön vermek gibi önemli rollere sahiptir. İnsanlar, yaşamlarını devam ettirebilmeleri için değişik bilgileri belleklerinde tutmak zorundadırlar. Örneğin, doğum tarihleri, telefon numaraları, suyun kaç derecede kaynadığı ve 2+2' nin 4 ettiği gibi değişik kategorilerdeki bilgiler bellekte depolanmaktadır. Depolama görevi ile beraber bellek, insan bilincinin üst seviye bilinç yetilerini de desteklemektedir. Bu nedenlerle bellek insan bilincinin en önemli unsurlarından biri olarak kabul edilmektedir.

Çeşitli bilgilerin depolanması, depolanan bilgilerin bellekte kalma sürelerinin farklılık göstermesi sebebiyle psikoloji bilimi belleyi kategoriler halinde ele almaktadır. Felsefe de bu noktada sorularla ile dâhil olmaktadır. Bu çeşitli kategorilerin ne olduğu, nasıl olduğu ve özelliklerinin neler olduğu gibi sorular ile ilgilenmektedir. Psikoloji disiplinine göre, bellek; uzun erimli bellek (Long-term memory), kısa erimli bellek (Short-term memory), ve duyusal bellek (Sensory memory) olmak üzere üç ana kategori ayrılmakta daha sonra bu kategorileri de kendi alt kategorilerine ayrılmaktadır. Uzun erimli bellek, bilgilerin uzun süre hatta insanın yaşam süresi boyunca depolandığı bellektir.

Bilgiler, kısa erimli bellekten ya silinirler ya da uzun erimli belleğe aktarılırlar. Uzun süreli bellek, açık (explicit) ve örtülü (implicit) bellek olmak üzere iki farklı alt kategoriye ayrılmaktadır. Bu ayrımın en önemli sebebi ise açık bellek 'bilinç'e gereksinim duyarken örtülü bellek 'bilinç'e gereksinim duymamaktadır. Açık bellek de kendi içinde iki farklı kategori de ele alınır. Olaysal bellek (episodic memory) ve anlamsal bellek (semantic memory) açık belleğin alt kategorileridir. Olaysal bellek ve anlamsal bellek birbirinin karşıtı olarak literatürde yer almaktadır. Bu iki farklı bellek ayrımı ilk olarak Tulving tarafından 1972'de yapılmıştır. Olaysal bellek, özel ve kişiye ait bilgilerin, geçmiş deneyimlerin depolandığı bellektir. Ayrıca, algı, anlama ve akıl yürütme gibi üst seviye bilişsel yetiler açık bellek alt kategorisi olan olaysal bellek tarafından desteklenmektedir. Olgusal belleğin önemli olmasının diğer bir sebebi ise bu bellek kategorisinin sadece insan bilincinde yer almasıdır. Sadece insan özgü olan tek bellek çeşididir ve başka hiçbir türde bulunmaz. Bu çalışmamızın ana unsurlarından biri olaysal bellektir. Çünkü olaysal bellek insan bilincinde önemli bir yere sahiptir. Bu önemi anlayabilmemiz için diğer kategorilerin de incelenmesi gerekmektedir. Anlamsal bellek, genel ve objektif bilgilerin depolandığı bellektir. Burada depolanan bilgiler sübjektif bilgiler olmadıkları için olaysal bellekte depolanan bilgiler gibi insandan insana değişiklilik göstermezler. Bu iki ayrı açık bellek arasındaki farklıklar çalışmanın üçüncü bölümde ayrıntılı bir şekilde ele alınacaktır. Örtülü bellek de aynı açık bellekte olduğu gibi iki farklı alt kategoriye ayrılmaktadır. Algısal bellek çıktılardan (output) duyusal girdiler (input) ile ilgili olan örtülü bellek alt kategorisidir. Yöntemsel bellek (procedural memory) bir şeyin nasıl yapıldığı ile alakalı örtülü bellek kategorisidir. Örneğin, piyano nasıl çalınır bilgisi yöntemsel bellekte depolanmaktadır. Bu iki farklı belleğin tek ortak noktası 'bilinç'e gereksinim duymamalarıdır. Liberman'a göre; açık bellek ve örtülü bellek ayrımı Graf ve Schacter tarafından 1985 yılında yapılmıştır. Uzun erimli bellek de çalışmanın üçüncü bölümde ayrıntılı olarak ele alınmıştır.

Belleğin diğer bir kategorisi ise kısa erimli bellektir. Bilgiler, 30-40 saniye arası olmak üzere kısa süreli bellekte depolanırlar. Bu süreç içerisinde ya silinirler ya da uzun süre depolanabilmeleri için uzun erimli belleğe aktarılırlar. Kısa süreli belleğe bilgiler duygusal bellekten iletilirler. Çünkü dışarıdan gelen duyular önce duyusal belleğe gelir oradan da kısa süreli belleğe iletilirler. Buradan da anlaşılacağı üzere çevreden gelen bilgiler ilk önce belleğin diğer bir kategorisi olan duyusal belleğe gelir, daha sonra kısa süreli olarak kısa erimli bellekte depolanır daha sonra uzun erimli belleğe aktarılır. Kısa süreli bellek daha sonra işler bellek (working memory) olarak değiştirilmiştir. İşler bellek, bilgiyi, okuma, basit akıl yürütme veya telefon numarasını hatırlama gibi daha basit bilişsel görevleri desteklemek amacıyla 2-15 saniye arası himayesinde tutabilmektedir. Aritmetik problem çözme ve dil öğrenme gibi bilişsel yetiler de işler bellek tarafından desteklenmektedir. Bu nedenle işler belleğin insan bilincindeki yeri yadsınamaz. Bellek ve belleğe ait kategoriler daha ayrıntılı bir şekilde üçüncü bölümde incelenmiştir. Çünkü olaysal belleğin insan bilincinde nerede yer aldığını görmek yapılan bu çalışma için önemli bir yer tutmaktadır. Aslında, belleği özellikle olaysal belleği bu kadar detaylı ele almamızın nedeni, çalışmamızın insan bilincinden çok Yapay Zeka ve düşünebilen makineler üzerine olmasıdır. Çünkü Yapay Zeka, insan bilinci göz önünde bulundurularak insan bilincini simüle eden makineler ile alakalıdır. Bu nedenle, olgusal bellek insan bilinci için ne kadar önemli ise Yapay Zeka için de o kadar önem arz etmektedir. Bu çalışmanın asıl amacı olgusal belleğin hem insan bilinci için hem Yapay Zekâ için önemini desteklediği üst seviye bilişsel yetiler sayesinde göstermektir. Eğer uygun bir olgusal bellek modeli geliştirilirse makinelerin insan bilinci kadar bilinçli olabileceği ileri sürülmektedir.

Yapay Zekâ alanı insan bilinci ile yakından alakalı olduğu için felsefe açısından özellikle zihin felsefesi açısından önemli sorgulama alanıdır. Felsefe, düşünebilen makinelerin mümkün olup olmadığı sorusu ile ya da makinenin düşünüp düşünemeyeceği sorusu ile ilgilenmektedir. Bu çalışma ise makinelerin düşünüp düşünemediği sorunundan ziyade belleğin özellikle olaysal belleğin Yapay Zekâ'da geliştirip geliştiremeyeceği sorunu ile ilgilenmektedir. Bu sebeple, Yapay Zekânın tarihsel gelişimine ve belleğin Yapay Zekâ'da gelişim sürecini incelemek doğru olacaktır. Çalışmanın ikinci bölümünde Yapay Zekâ'nın tarihsel gelişimi, ortaya çıkışı ve Yapay Zekâ'da belleğin gelişimi ele alınmaktadır.

Düşünebilen makine iddiası asırlar önce Mısırlılar tarafından milattan önce 200'lü yıllarda ortaya atılmıştır. O zamandan günümüze kadar birçok gelişme göstermiş ve hala göstermeye devam etmemektedir. Yapay Zeka'nın kökleri asıl olarak milattan önce 2500'lere dayanmasına rağmen bilimsel olarak temelleri 1956'da Dartmouth'ta yapılan konferansta atılmış ve ilk olarak Yapay Zeka adı orada geçmiştir. Konferansa birçok araştırmacı takılmış kendi fikirlerini söylemiş ve bilgi alışverişinde bulunmuşlardır.

Düşünebilen makinelerin gelişimi, toplama ve çıkarma yapabilen ilk otomatik hesap makinesi ile 1642'de başlamıştır. Dünyadaki ilk otomatik hesap makinesi olarak kabul edilen bu makine Blaise Pascal tarafından icat edilmiştir. Diğer bir önemli gelişme de Charles Babbage tarafından 1842'de yapılmıştır. 'Analytical Engine' olarak adlandırdığı ve mantıksal çözümlemeler yapan ilk bilgisayarı tasarlamıştır. İlk başta başarılı olamayan bu makine zaman içerisinde geliştirilmiştir. Yine de Yapay Zekâ için önemli bir gelişme olarak kabul edilebilir. Direk bir katkısı olmamasına rağmen Frege'nin de Yapay Zekâ'ya önemli katkıları olmuştur. 1879'da makinelerin ihtiyaç duyduğu dili sembolik dili geliştirerek katkı sağlamıştır. Yapay Zekâ'nın bilinen en önemli bilim adamı Alan Turing'dir. Turing Makineleri olarak bilinen makinelerin programlamacısıdır. 1950'de makineler için zeki olabilme kriterlerinden bahsettiği en ünlü makalesi 'Computing Machine and Intelligence' 'ni yazmıştır. Makalede 'makine düşünebilir mi?' sorusunu ele almaktadır. Turing Makinesi zaman içerisinde geliştirilmiş ve geliştirilen bütün Turing Makineleri 'Ulusal Turing Makineleri' (Universal Turing Machines) olarak anılmaya başlanmıştır.

Dartmouth Konferansından bir yıl sonra 1957'de Yapay Zeka alanındaki bir diğer önemli gelişme Newell, Show ve Simon tarafından yapılmıştır. Problem, teorem çözmek ve santraç oynamak gibi çeşitli birçok problem çözebilen programı, Genel Problem Çözücü (General Problem Solver, GPS)'yü tasarlamışlardır. Bu makine, McCulloch ve Pitts tarafından insan gibi düşünebilen ilk program olarak kabul edilir. Yapay Zekâ'nın gelişmesine önemli ve çeşitli katkıları olan diğer bir araştırmacı ise John McCarthy'dir. İlk olarak, 1958'te '*Programs with Common Sense'* adı ile yazmış olduğu yazısında tamamlanmış ilk Yapay Zekâ programı olan 'Advice Taker' ı tanıtmıştır. İkinci olarak, Massachusetts Teknoloji Enstitüsü (MIT)'de Minksy ile beraber Yapay Zekâ laboratuarı kurmuştur. Son olarak da, hala kullanılmakta olan LIPS adındaki Yapay Zekâ dilini 1958'de tanıtmıştır. Görülebileceği gibi Yapay Zekâ alanındaki önemli gelişmeler Dartmouth konferansı ile beraber gelişiyor. 1966'da yapılan Dartmound konferansından katılımcılar tarafından Yapay Zekâ'ya değişik tanımlar yapılmış ve ortak bir karar ile Yapay Zekâ'nın bilgisayarlar ile olduğuna karar verilmiştir. Yapay Zeka'ya dair basit kabul edilebilecek tanım Russell ve Norvig tarafından 1995'de yapılmıştır. Russell ve Norvig Yapay Zekâyı dört farklı kategori de tanımlamaktadır.

1. İnsan gibi düşünebilen makine ya da sistem.
2. İnsan gibi davranabilen makine ya da sistem.
3. Mantıklı düşünebilen makine veya sistem.
4. Mantıklı davranabilen makine veya sistem.

Farklı diğer bir tanım ise Searle tarafından yapılmıştır. Zayıf Yapay Zeka (Weak AI) ve Güçlü Yapay Zeka (Strong AI) olmak üzere iki farklı kategoride tanımlıyor. Zayıf Yapay Zekâ, zekânın bazı unsurlarına sahip olan sadece mantıklı davranabilen makinler ile ilgiliyken, Güçlü Yapay Zeka ise gerçek düşünce ve bilince sahip hatta mantıklı düşünme yetisi olan makinelerle ilgilidir. Fakat Yapay Zekâ, insan zekâsını temel aldığı için zekânın bütün unsurlarını barındırması gerekmektedir. Bu nedenle, insan zekânın en önemli unsurlarından biri olan 'bellek' ile de bağlantısı olması gerekmektedir. Bu çalışmada da amaçlanan bir makinenin belleğe özellikle olgusal belleğe sahip olup olmadığı veya olgusal belleğin geliştirilip geliştirilemeyeceğidir. Bu sebeple, Yapay Zekâ'nın gelişiminin bellek, özellikle olaysal bellek yönünden incelenmesi önem taşımaktadır.

Von Neumann depolanmış program hakkında yazan ilk kişi olarak kabul edilir olsa da 'depolama' yeteneğine sahip olan ilk program, 1832 yılında adreslenebilir bellek fikirleri, depolanmış-program ve koşullu atlar olarak Charles Babbage tarafından 1946 yılında icat edilmiştir. Depolanmış simge ve numaraları kullanabilen makinenin adı 'Analytical Machine'dir. Depolanmış programın geliştirilmesinde en önemli rol oynayan figür Alan Turing'dir. Turing iki tarafta hareket etmek için tarayıcıda yer alan bir sınırsız bellek ile soyut bir dijital makine tasarlanmış ve böylece 1936 yılında modern bilgisayarın ilkesini geliştirmiştir. Tarayıcı bellek üzerinden ileri ve geri olmak üzere iki yöne doğru hareket edebilmektedir. Bundan başka, tarayıcı bellekte saklanan bir talimatlar programı sayesinde çalışır. Bu saklı program kavramı ve Turing'in hesaplama makineleri her türlü Turing Makinesi olarak bilinir. Claude Shannon ayrıca Yapay Zekânın gelişiminde diğer önemli bir figürdür. 1938 yılında 'A Symbolic Analysis of Relay and Switching Circuits' başlıklı bir makale yayınladı. Karmaşık elektrik sistemleri hakkında kâğıt gibi ağların özelliklerinin matematiksel analizini yapmak için yazılmıştır. Onlar, aç-kapat (on-off) anahtarları ile çalışan, böylece bu sistemlerin devrelerin oluşmaktadır. Ayrıca, 1945 yılında, Turing elektronik depolanan programın tam kriterlerini ilk defa bildirdi. Aynı zamanda genel amaçlı bilgisayarı 'Proposed Electronic Calculator' olarak tanımlamıştır. Aynı yıl, bir elektronik depolanmış program olan genel amaçlı dijital bilgisayar EDVAC, von Neumann tarafından icat edildi. Neumann saklı-programın fikrini geliştirmeye çalıştı. Bu nedenle, bir bilgisayar, bilgisayarın dâhili bellekte depolanan talimatlar sayesinde çalışabileceğini gösterdi. Böylece, o bilgisayarda program ve depolama veri için aynı dil kullanılması gerektiğini, böylece bilgi depolama ile birlikte ikili mantık ve aritmetik çalışmalar yapanın mümkün olduğunu gösterdi. EDVAC'ın ortaya çıkmasından bir yıl sonra, depolanmış program kavramı üzerinde ilk modern yazı da Von Neumann tarafından yazılmış ve o bilgisayarlar üzerinde araştırma yapmaya başlamıştır. Von Neumann'ın makineleri yapılan mimari donanımlar sayesinde, programlama ve veri olarak bir bilgisayarın bileşenleri tarafından takip edilecek bir genel yapısını tanımlaması Yapay Zekânın gelişimi için önemlidir.

Neumann mimarisi, bellek alt birimi, aritmetik-mantık birimi ve kontrol ünitesi olmak üzere üç ana bölümden oluşmaktadır. Ayrıca, bu üç ana bileşen birbirleri ile etkileşim. Ana bellek veri ve talimatları saklar iken, kontrol ünitesi hafızasında yer alan talimatları çözer ve onlar sayesinde birimi yürütür. Von Neumann makineleri incelendiği zaman bellek açısından önemli gelişmelerin olduğu açıkça görülmektedir. Bu gelişmelerle beraber, 1950'de Turing makinenin insan zekasına erişebilmesinin şartının bir belleğe sahip olması gerektiğini ileri sürmüştür. Bu nedenle, makinenin hedefe ulaşmak ve sorunları çözmek için bellek ihtiyacını olduğunu söylemek doğru olacaktır.

Expert (uzman) sistemler, Yapay Zekâ alanındaki önemli gelişmeler arasında kabul edilmektedir. Expert sistemler sadece belirli bir alanda uzman olan istemlerdir.1960 yılında, Marvin ve onun öğrencisi, Evan Yapay Zekâ'nın gelişiminde önemli rol oynamıştır. Evan görsel sıralama ve analojiler çözmek için büyük bir hafızaya sahip olan karışık programlanmış bir makine tasarladılar. Yapay Zekâ gelişiminde diğer önemli buluş ise DENDRAL projesi olarak adlandırılan 1965 yılında Stanford Üniversitesi'nde Buchanan, Feigenbaum ve Lederberg işbirliği ile yapılmıştır. DENDRAL organik bileşikleri analiz etmek için tasarlanan ilk uzman sistemdir. Russell ve Norvig'e göre, uzman sistemler bilgi temelli (knowledge-based) sistemlerdir. Yapay Zekâ'nın tarihsel gelişiminde uzman sistemler ile karşılaşmak mümkündür. Bu çalışmada önemli olan uzman sistemlerden bahsedilmeye çalışılmıştır.

Schank, Yapay Zekâ gelişiminde önemli katkıları olan araştırmacılardan biridir. Schank ve meslektaşları bellek sayesinde doğal dili anlamanın gelişimi üzerinde çalışmışlardır. Sıradan kalıplaşmış durumlar hakkında bilgi veya hesap vermek üzere 'senaryo' kavramı tanımlanmışlardır. Senaryo, bir kelime ya da komut dosyaları olarak tanımlanabilir. Senaryo; bir doktor randevusu alma ve restorana gidildiğinde yapılması gerekenler bilgisi, günlük durumları tanımlamak için bilgi temsili sistemdir. Bir komut dosyası sadece belli durumlarda nasıl davrandığımız ve bu durumlar hakkında neler bildiklerimiz ilgilidir. Örneğin, bir hasta doktordan randevu alırken gerekli olan en uygun bilgi komutunu kullanmaktadır.

Dizelerin en önemli özelliği 'bellek yapısı' türünde olmalıdır ve sadece belli durumlar hakkındaki bilgiyi depolarlar. Schank ve Alben senaryoyu aynı türde olan yeni deneyimleri kodlamak için belirli türdeki eski deneyimleri depolama yeri olarak tanımlıyorlar. Böylece, bir bilgisayar veya program insanlar gibi komut vasıtasıyla tipik durumlar hakkında hikâyeleri anlayabilirler. Schank ve meslektaşları, komutlar vasıtasıyla sorulara cevap verebilen, makale okuyabilen SAM (Script Applier Mechanism) adında bir program geliştiler. Program, giren veriler arasında nedensel bağları anlayıp çıkarım yapabilme özelliğine sahiptir. Program bellek açısından Yapay Zekâ gelişimi üzerinde önemli bir role sahiptir. Çünkü programın düzgün bir çıkarım yapmak ve bellekte hikâyeyi kullanarak iyi çözümler vermek gibi yeteneklere sahiptir. Bir senaryo kuramının bellek açısından Yapay Zekâ'nın gelişmesine katkı sağlayacağını söylemek mümkündür.

1970'lerde yapılan önemli çalışmalarda uzman sistemler ile alakalıdır. Öncelikle, Cornell Frank gözlerinin önünde harfleri tanıma yeteneğine sahip bir görsel algı makinesi tasarlamıştır. İkinci olarak, Patrick Piston sadece önündeki nesneyi tanıyabilen değil aynı zamanda bu karşıt taraf arasındaki farklılıkları gösterebilen bir program tasarlamıştır. Üçüncü olarak, David Vals ekranın analizi ile ilgili olan bir program tasarlanmıştır. Ayrıca, program aynı ekranda farklı nesneleri de tanıyabiliyor. Son olarak, diğer görsel program görsel sistemlerin karakterizasyonu göstermek için Marr tarafından tasarlanmıştır. 1970'lerdeki gelişmeler hakkında bahsedilen görüşlerin ışığında, uzman sistemlerin Yapay Zeka açısından önemli gelişme sağlamışlardır.

Bilişsel mimariler (Cognitive Architectures) Yapay Zeka gelişiminin diğer yanıdır.. Bilişsel Mimarlık düşünce yapısı ile ilgili olan bilişsel bilimler ve zeka görünümü ile ilişkilidir. Buna ek olarak, bilişsel mimari; davranışın yapısal modellerinin bir tasarım olarak tanımlanır. Aslında bilişsel mimari iki bölümden oluşmaktadır; (1) bilişsel ve (2) mimari. Bilişsel; dil yetenekleri ve insan becerilerinin edinimiyle ilgili olmakla birlikte, mimari modelleme veya zihin, zeka veya biliş hesaplama tasarımı olarak da adlandırılır. Aynı zamanda bu mimariler teoriktir. Yazılım mühendisliği ile alakası yoktur. Üst düzey bilişsel yetileri sayesinde bilinen en önemli bilişsel model "Bilişsel Mimari Soar" (The Soar Cognitive Architecture)' dır dır. Bu mimari olaysal ve anlamsal belleğe sahiptir. Aynı zamanda, sorun çözme ve takviye öğrenme yeteneği vardır. Bu bilişsel mimari, işlevsel açıdan insan zekâsına daha yakındır. Bu bilişsel mimari, dördüncü bölümde özellikle olaysal bellek açısından ayrıntılı olarak incelenmeye çalışılmıştır.

Soar Bilişsel Mimarisi'ndeki olaysal belleği analiz etmeden önce, bilişsel mimariler için olaysal belleğin neden önemli olduğu sorusunu açıklamak gerekmektedir. Aynı zamanda, Soar mimarisindeki genel bellek sistemini de incelemek olaysal belleğin önemini açıklamamıza katkı sağlayacaktır. Daha önce de bahsedildiği gibi olaysal bellek 'kişinin kendi tarihine' ilişkin sübjektif bilgilerin depolandığı ve gerektiğinde hatırlamanın sağlandığı bellek türüdür. Bununla beraber, kişisel geçmiş deneyimlere ve sübjektif bilginin depolanıp hatırlanması bazı üst düzey bilişsel yetileri desteklemektedir. Nuxoll (2007)'e göre, algılama, muhakeme ve öğrenme gibi çeşitli bilişsel yetiler "kişisel tarihini bilmenin' vasıtasıyla kolayca gerçekleşirler. Bu nedenle, algılama, muhakeme ve öğrenmenin olaysal bellek tarafından desteklenen en önemli yetiler olduğu oldukça açıktır. Ayrıca, olgusal bellek, bilişsel mimarilerdeki bilişsel yetileri geliştirmek için uygun bir bellek türü olabileceğini kabul edilebilir. Öncelikle, olaysal belleğin mimarilere ana katkısı zamansal yapının gereği davranışı ve çevre tahminini kolaylaştırmasıdır. İkincisi, olaysal bellek Yapay Zekâ'da bazı bilişsel yetileri kolaylaştırır. Laird, Nuxoll ve Derbinsky (2007), soyut düzeyde, olaysal belleğin akıl yürütme ve öğrenme yeteneklerini geliştirmek için önceki olayların depolanmasını sağlayan bir bellek olduğu iddiasında bulunmuşlardır. Üçüncü olarak, eylemi gerçekleştiren özne (agent) olaysal bellek vasıtasıyla geçmişiyle ilgili sorulara cevap verebilir. Son olarak, olaysal bellek sayesinde eylemi gerçekleştiren özne gelecekteki eylemlerini tahmin edebilmek için geçmiş eylemin sonuçlarıyla ilişki kurabilmektedir.

Aslında, Soar Bilişsel Mimarisi 2012 yılında John E. Laird tarafından analiz edilmiştir. Analizin üç ana amacı bulunmaktadır. İlk olarak, Soar bilişsel mimarisi, neden tasarlandığı ve nasıl çalıştığı göz önünde bulundurularak tanımlanıyor. Analizin ikinci hedefi ise bilişsel mimari tanımını destekler niteliktedir. Nihai hedef ise bilişsel mimari değerlendirerek Soar Mimarisi gibi insan bilişi seviyesindeki özneleri desteklemek amaçlıdır. Soar Bilişsel Mimarisi, olaysal belleğin yanında işlemsel belleğe, anlamsal belleğe ve işler belleğe de sahiptir. İşler bellek mimarinin en önemli parçasıdır. Çünkü işler bellek sayesinde olaysal, anlamsal bellekteki ve çevreden gelen bilgiler mimari tarafından kolayca hatırlanabilir. Anlamsal bellek ise, insan bilincinde yer alan anlamsal belleğe oldukça benzemektedir. Fakat olaysal bellek insanlardaki olaysal bellekten farklıdır. Olaysal bellek, işler belleğinin çalışabilmesi için anlık depolama yapmaktadır. Olaysal bellek, olaysal öğrenmeyle alakalı iken anlamsal bellek anlamsal öğrenme mekanizması ile alakalıdır. Aslında, iki bellek türünün tek ortak özelliği vardır. Her iki bellek de işler bellekteki yapılar sayesinde sahip oldukları bilgileri hatırlayabilirler.

Soar Mimarisinde yer alan olaysal bellek, insanlardaki olaysal belleğin ortak işlevleri göz önünde bulundurularak tasarlanmıştır. Genellikle, Soar Mimarisi’ndeki olaysal ve işler bellek doğrudan bir şekilde birbirleri ile etkileşim içindedirler. Olay, olaysal bellete saklandığında, olay işler belleğin unsuru haline gelir. Ayrıca, olay, zamansal bilgiyi de taşıdığı için geçmiş ve yeni olay kolayca hatırlanabilir. İşler bellekteki bilgi, olaysal depolama modeli vasıtasıyla olaysal belleğe kodlanır. Ayrıca, eylemi yapan öznenin olayı, işler belleğe kurduğu ipuçları sayesinde elde etmesi mümkündür. Ayrıca, Laird, Nuxoll ve Derbinsky göre, olaysal bellek zaten ziyaret edilmiş yerlerin, kullanılmış operatörleri ve üretilen sonuçların özellikleriyle ilgili geçmiş deneyimleri içermektedir. Olaysal bellek, Soar Mimarisi’nde desteklediği üst seviye bilişsel yetileri desteklemesi sayesinde önem kazanmaktadır. Üç önemli bilişsel yeti olaysal bellek tarafından desteklenmektedir. Bunlardan ilki, algılama (Perception), ikincisi akıl yürütme (Reasoning) ve üçüncüsü öğrenme (Learning)’ dir. ‘Algılama’ görme işitme, koku, dokunma ve tat gibi duyular vasıtasıyla çevrede meydana gelen şeylerin farkında olmak demektir. Algısal işlem, durumsal farkındalık gibi olaysal bellek tarafından desteklenmektedir. Olaysal bellek sayesinde, eylemi gerçekleştiren özne benzer bir durum daha önce algılanan veriler ile mevcut algı arasında bir ilişki kurabilmektedir. İkincisi, olaysal bellek tarafından desteklenen diğer üst düzey bilişsel yeti 'akıl yürütme' dir. Muhakeme, eylemi gerçekleştiren öznenin kendi tarihini bilmesi gelecek eylemleri tahmin etmek ve geçmiş eylemi açıklamak için gereklidir. Kendi tarihini bilmek de ancak olaysal bellek ile mümkündür. Son olarak, olaysal bellek tarafından desteklenen diğer önemli üst düzey bilişsel yeti öğrenmedir. Öğrenme, süreç isteyen bir bilişsel yetidir. Önceki deneyimler gerekli oldukları zaman kadar olaysal bellek tarafından depolanır ve zamanı geldiği zaman kullanıma hazır hale getirilir. Laird'e göre olaysal bellek bir öğrenme mekanizmasıdır. Geriye dönük öğrenme, olaysal bellek tarafından desteklenir. Sonuç olarak, olaysal bellek tarafından desteklenen üst düzey bilişsel yetileri incelediğimiz zaman olaysal belleğin Soar Mimarisi'nde olduğu gibi diğer bütün mimariler için de önem taşıdığını söyelebiliriz. Soar Bilişsel Mimarisi, olaysal bellek eklenerek bu üst düzey bilişsel yetilerin desteklendiği en önemli mimaridir. Sadece bu yetiler değil, diğer bazı önemli özellikleri de olaysal bellek tarafından desteklenmektedir. Elbette, olaysal bellek tarafından bütün üst düzey bilişsel yetileri mimarilere kazandırmak mümkün değil. Çünkü olaysal bellekteki bilgiler deneyimle alakalıdır ve deneyim sayesinde depolanırlar. Diğer bir değişle, sembolik değillerdir ve sembolleştirilerek aktarılamazlar. Aynı zamanda, deneyim bazlı bir bellek türü olduğu için sadece insanlara özgü bir bellek türü olduğunu da söylemek mümkündür. Bu nedenler ışığında, sadece bazı üst düzey bilişsel yetiler bilişsel mimarilerde desteklenirler. Mimariler deney imlemekten ziyade sembolleştirme yoluyla ve girdi-çıktı yöntemine göre tasarlanmaktadırlar. Olaysal bellek tarafından desteklenen bilişsel yetileri ekleyebilmek için hem deneyimlime özelliğinin hem olaysal belleğin mimariler için geliştirilmesi gerekmektedir.

Bu çalışmanın amacı, Yapay Zekâ'da olaysal belleğin neden önemli olduğunu sorgulamaktır. Bu nedenle, Yapay Zekâ, bellek gibi farklı bir bakış açısı ile ele alınmıştır. Olaysal belleğin varlığı ya da yokluğu söz konusu olduğunda Yapay

Zekâ'nın gelişimi üzerine bir inceleme söz konusudur. Basit bir şekilde sadece olaysal belleğin varlığı değil, aynı zamanda desteklediği üst seviye bilişsel yetiler de ele alınmıştır. Olaysal belleğin Yapay Zekâ ile ilişkisi üst düzey bilişsel yetiler açısından analiz edilmiştir. Elbette, analiz yapılırken felsefi unsurlara dikkat edilmiştir. Çünkü inceleme varlıksal ve bilgisel temeller içermektedir. Sonuç olarak, şu denilebilir ki olaysal belleğin eksikliği durumunda, tam anlamıyla hareket edebilen ya da yapılan Yapay Zekâ tanımlarına uygun bir Yapay Zekâ'dan bahsetmek mümkün değildir. Bellek ne kadar insan zekâsı ve bilinci için önemli ise Yapay Zekâ'nın gelişimi içinde oldukça önemlidir. Bu nedenle, uygun bir olaysal bellek modeli tasarlandığı takdirde, insan zekâsına yakın ya da yapılan tanımlara uygun bir Yapay Zekâ'dan bahsetmek mümkün olabilir. Bu nedenle de, Yapay Zekâ'daki belleğin episodik bellek olduğuna dair güçlü de bir argümana sahip olmalıyız.

TEZ FOTOKOPİSİ İZİN FORMU

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TEZİN ADI (İngilizce) : THE ROLE OF EPISODIC MEMORY IN ARTIFICIAL INTELLİGENCE?

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