Running head: SEMANTIC MEMORY: THEORIES, MODELS, AND TESTS

Neuropsychology of Semantic Memory: Theories, Models, and Tests

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Härmed intygas att allt material i denna rapport, vilket inte är mitt eget, har blivit tydligt identifierat och att inget material är inkluderat som tidigare använts för erhållande av annan examen.

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Abstract

Semantic memory is part of the long-term memory system, and there are several theories concerning this type of memory. Some of these will be described in this essay. There are also several types of neuropsychological semantic memory deficits. For example, test results have shown that patients tend to have more difficulties naming living than nonliving things, and one probable explanation is that living things are more dependent on sensory than on functional features. *Description of concrete concepts* is a new test of semantic memory, in which cueing is used, both to capture the maximum performance of patients, and to give insight into the access versus storage problem. The theoretical ideas and empirical results relating to this new test will be described in detail. Furthermore, other tests of semantic memory that have been commonly used will also be briefly described. In conclusion semantic memory is a complex cognitive system that needs to be studied further.

Keywords: Semantic memory, concrete concepts, category-specific impairments, semantic features, conceptual hierarchies

1. Introduction

Memory is a complex aspect of human cognition, and consists of several different types of memory systems (Garrard, Perry & Hodges, 1997; Laatu, 2003). Generally, the memory system is divided into short-term memory and long-term memory, which both can be divided further into even smaller and more specific units. The long-term memory system is divided into declarative and nondeclarative memory (Gazzaniga, Ivry & Mangun, 2002). Impairments in any of the different memory systems can occur immediately due to direct damage to the brain, or develop gradually as a cause of disease.

Many neuropsychological deficits include difficulties with memory. A person who is frequently complaining about forgetting things is likely to express the first symptoms of some type of neuropsychological deficit (Garrard et al., 1997), although it is important to remember that memory decline is a natural part of ageing as well. In contrast to normal ageing, however, neuropsychological deficits include both memory decline as well as other types of cognitive impairments, such as difficulties with language (Laatu, 2003). Dementia is a progressive decline in cognitive function and is considered a major public health issue. Dementia affects mostly people over 65 years of age. In Sweden, the prevalence rate among people over 65 years of age was approximately seven percent in the year of 2005 (Vårdguiden, 2007), and this percentage increases with higher age (Laatu, 2003).

In this essay I will describe semantic memory, which is, together with episodic memory, a part of the declarative memory system (Gazzaniga et al., 2002). Semantic memory has not been as frequently studied as episodic memory, but both types of memory are known to be impaired in connection with dementing diseases. However, it is only in dementia of

Alzheimer's type, which is the most common type of dementia, that the semantic memory deficits are generally accepted as a central part of the disease (Laatu, 2003).

In the first part of this essay I will describe the phenomenon of semantic memory, as well as some of the theories and deficits related to it. In order to describe the complexity of this memory system, and to put its deficits into context, a few diseases in which semantic memory may be impaired are briefly presented.

In the second part of this essay the most commonly used tests are briefly described. I will also explain why it is important to study semantic memory with several types of tests. Then a test that has recently been developed will be described and presented in more detail.

The aim of this essay is to present semantic memory as an independent aspect of declarative memory, and to describe its complexity. Another aim is to describe some of the problems occurring because of this complexity, which make it difficult to study the patients suffering from these types of deficits.

2. Semantic memory

2.1. Definition of semantic memory

The long-term memory system consists of declarative and non-declarative memory. Declarative memory is the knowledge that we have conscious access to, and consists of semantic and episodic memory. Non-declarative memory is the knowledge that we have no conscious access to. Procedural memory is a part of non-declarative memory (Gazzaniga et al., 2002).

Semantic and episodic memory differs from each other in that episodic memory contains information about personal events and episodes which are time and space specific. Episodic memory can not be shared with others in the sense that everyone has direct access only to their own personal memories. Semantic memory, on the other hand, contains factual information. It is not related to the occasion of learning, as is episodic memory. Rather it concerns the specific information that was learned during the occasion. Semantic knowledge can be shared with others in the sense that semantic memory is not related to any personal memories (Laatu, 2003). Procedural memory contains information about how things are done (Tulving, 2003). When riding a bicycle, for example, procedural memory process information about how we keep balance, semantic memory relates the bicycle to other concepts, such as a helmet, and episodic memory allows us to remember specific occasions related to bicycles.

At first, semantic memory was thought to be an organized knowledge of words (Laatu, 2003), and necessary for the use of language, since it contains information and knowledge of the world, knowledge of objects, facts, concepts, features and words and their meanings (Tulving, 1972; Hodges, Salmon & Butters, 1992; Garrard et al., 1997; Laatu, 2003). Today also non-verbal knowledge about the world is included in semantic memory (Laatu, 2003). Thus, in semantic memory we store information about concrete and abstract concepts, such as “house”, “cat”, and “comedy”. Here we also store features of the concepts, such as “a house can be made of wood”, and “a cat says meow”, as well as information about the relationships between concepts (Portin, Laatu, Revonsuo & Rinne, 2000; Laatu, 2003).

2.2. Theories of semantic memory

There are several theories of semantic memory, and here three of them will be presented. The theories presented are Tulving’s theory, the hierarchical structure theory, and feature-based theories of semantic memory. The reason I have chosen these theories is that they describe semantic memory from different aspects. The first theory describes semantic memory in relation to procedural and episodic memory, the second theory describes how the information within semantic memory may be organized, and the third theory describes both a probable organization of, and relations between, semantic knowledge.

Since there are different types of theories of semantic memory, and since none of these theories, nor the methods used to test them, are accepted by all researchers, the study of semantic memory has lead to contradictory results. One important explanation for this contradiction is that the theories may concern different aspects of the memory, instead of describing the phenomenon as a whole (Laatu, 2003).

2.2.1. Tulving's theory

The theory presented by Tulving (2003) describes how semantic memory is related to procedural and episodic memory, and does not aim to describe how information in semantic memory may be structured. According to Tulving (2003), the three types of memory are characterized by different types of consciousness. Procedural memory is characterized by anoetic consciousness, semantic memory by noetic consciousness, and episodic memory by autonoetic consciousness.

Anoetic consciousness means, literally, *nonknowing* consciousness, and contains information that is temporally and spatially bound to the current situation. This information is called anoetic since we are not aware of processing it, but still it allows us to behave appropriately in relation to the environment (Tulving, 2003). When riding a bicycle, for example, we are not aware of how we keep balance, or what the exact mechanism is behind steering and so on. But we are able to ride the bicycle anyhow, since the information required is processed in procedural memory.

Noetic consciousness means, literally, *knowing* consciousness. This type of consciousness allows us to be aware of, and to cognitively operate on, objects and events and their relations, in the absence of the objects and events (Tulving, 2003). Noetic consciousness allows us to imagine a bicycle and relate it to other things, such as a helmet, and to events such as the knowledge that one can ride a bicycle during summer. The noetic knowledge of objects and events is general and is not connected to any personal past events, as is the information in autonoetic consciousness. Thus, the events in semantic memory differ from those in episodic memory.

Autonoetic consciousness means, literally, *self-knowing* consciousness, and is necessary for the remembering of personally experienced events. It is autonoetic consciousness that allows us to relate the bicycle in the previous examples to specific events in our personal past, such as remembering a specific bicycle ride (Tulving, 2003). Figure 1 illustrates this.

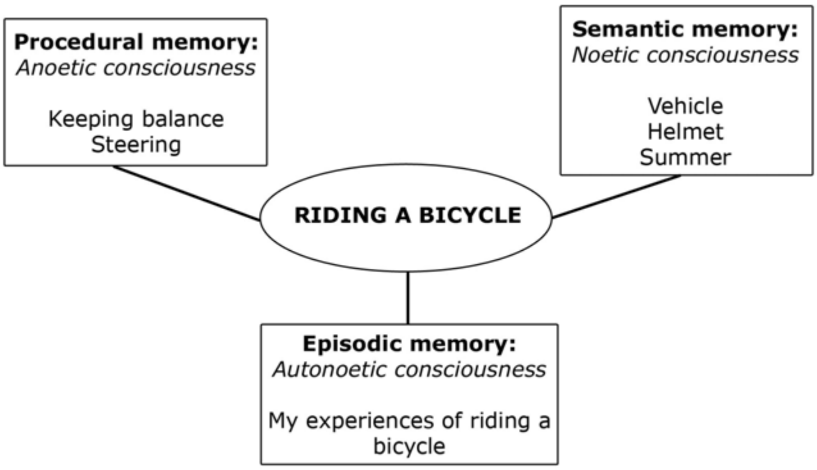

Figure 1. A model of how the three different types of memory are connected according to the theory presented by Tulving (2003).

2.2.2. The hierarchical structure theory

The hierarchical structure theory is a theory of semantic memory organization. This theory suggests that semantic knowledge is organized hierarchically in the memory system, where it is divided into three different levels of information. In these levels of information superordinate categories, subcategories and individual exemplars of the subcategories are represented (Garrard, Lambon Ralph, Hodges & Patterson, 2001).

The superordinate categories, which are large and general, are represented at the highest level of information, and examples of superordinate categories are “animal”, “vehicle” and “food”. At the second level of information, the subcategories are represented, and here more specific information of the large and general superordinate categories is found. As can be seen in Figure 2, some examples of subordinate categories in the category of food are “fruit”, “rootcrop”, and “vegetable”. The lowest level of information in the hierarchical structure contains the specific exemplars of the subcategories, and as can be seen in the figure, examples of specific exemplars in the category of fruit are “lemon” and “pear”.

A specific pattern of progressive semantic memory impairments has been noticed among patients suffering from semantic memory deficits, as the patients seem to gradually lose their ability to use information stored in the semantic memory. This gradual loss affects the ability to mention specific exemplars of categories already at the early stages of the impairment, while the ability to mention superordinate categories is preserved for the longest time. This pattern is called a bottom-up breakdown in the structure of semantic memory, and offers support for the hierarchical structure theory (Hodges et al., 1992; Garrard et al., 2001; Garrard, Lambon Ralph, Patterson, Pratt & Hodges, 2005).

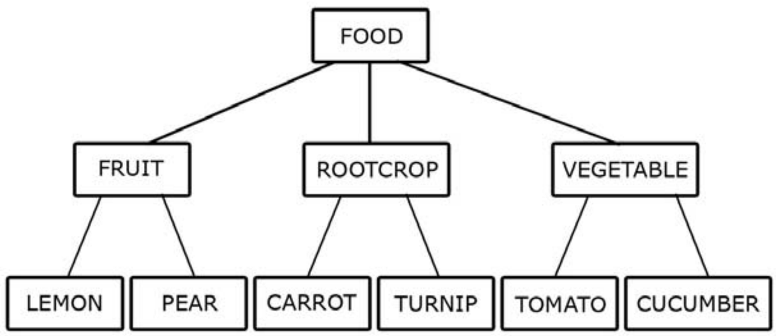

Figure 2. An example of a hierarchical structure (Laatu et al., 1997).

2.2.3. Feature-based theories

Feature-based theories are those that concern the organization and internal structure of semantic representations. According to these theories, semantic knowledge is composed of small units of information, so called semantic features. However, there are differences between these theories that concern the organization of the semantic features in memory. Some feature-based theories suggest that the semantic features are organized into two levels of knowledge. The first of these levels is the category-level, which contains information about features that are shared by many concepts in a specific category. Thus these features are non-distinguishing, and as can be seen in Figure 3, examples of shared features in the category of mammals are “has eyes”, “has legs”, and “produce milk”. The second level is the exemplar-level, which contains information about distinguishing features, that is, features that are not shared by all concepts in a category. Rather these features are a distinguishing part of a specific exemplar in a category. For example, a very unique distinguishing feature for elephants is that they have a trunk (Garrard et al., 2001; Garrard et al., 2005).

Other feature-based theories suggest that semantic features are organized categorically in semantic memory. Thus all features in a certain category are gathered at the same place, and no distinction between distinguishing or non-distinguishing features is made. The problem with this type of organization is, as can be seen in Figure 4, that not all concepts can be organized into one single category, since category membership may be both unclear and multiple. The concept “horse”, for example, could be categorized both as an animal, and as a vehicle, while the concept “tomato” botanically is a fruit, but is used as a vegetable (Garrard et al., 2001).

Despite this problem, there seems to be evidence for categorical organisation in semantic memory. Studies have shown that category-specific impairments of semantic memory do occur between the categories of natural kind (living things), and man-made artefacts (nonliving things). One explanation for how this can be possible is that living things seem to be more dependent on perceptual features, while non-living things are more dependent on functional attributes (Garrard et al., 2001; Gazzaniga et al., 2002).

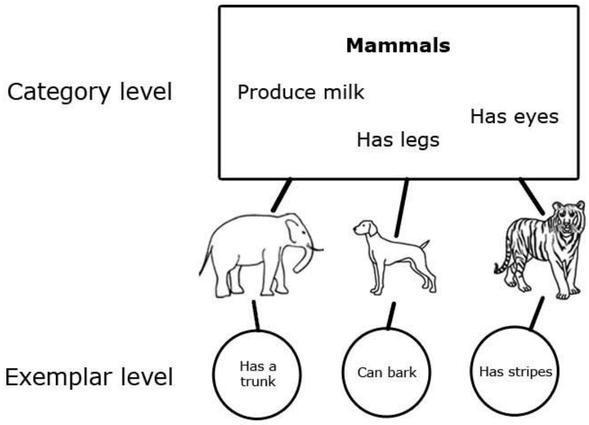

Figure 3. A model of a two-level organization of semantic features.

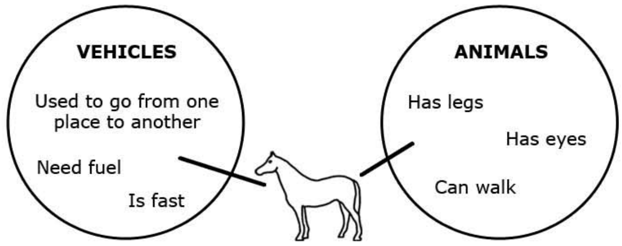

Figure 4. A model of categorical organization

2.3. Semantic memory deficits

There has been a long debate on whether the semantic memory impairments are due to an access deficit, or to a degradation of semantic knowledge. When semantic knowledge is used, the information needs to be brought into working memory from semantic memory, and this system could be impaired in two different ways, which is demonstrated by Figure 5. Some researchers believe that the semantic memory deficits are due to an impaired access to semantic memory. According to these, semantic knowledge is difficult to activate and bring into working memory where it can be used. Other researchers suggest that the deficits of semantic memory are due to impairments of the semantic knowledge itself (Laatu, Portin, Revonsuo, Tuisku & Rinne, 1997). Still other researchers believe that the semantic memory impairments are partially caused by access deficits, and partially by degradation of the semantic knowledge (Laatu, 2003).

This problem is of theoretical importance since an impaired access to semantic knowledge would mean that the semantic representations themselves are still intact, and therefore could still be used, if only there were other ways of gaining access to the information (Hodges et al., 1992; Garrard et al., 1997). Even in the light of the currently available empirical evidence it is difficult to tell whether the semantic memory deficits are due to access impairments, or to a degradation of semantic knowledge itself (Laatu, 2003). I will in this section describe semantic memory deficits as if they were caused by degradation of semantic knowledge, and not by an access deficit, in order to not complicate the issues unnecessarily and to keep the description easy and understandable.

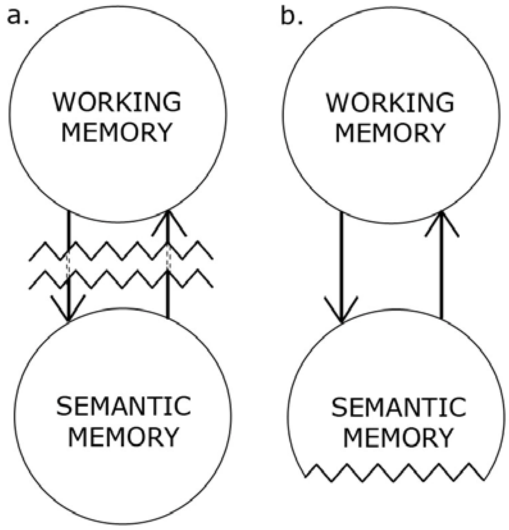

Figure 5. Semantic memory deficits can be caused by an access deficit (a.) or by a degradation of semantic knowledge (b.).

2.3.1. Category-specific impairments

There are several different types of semantic memory deficits, and it has been noticed that the deficits often form highly specific patterns of impairment. For example, there are some patients who show semantic memory deficits related to abstract concepts, and others who show deficits related to concrete concepts. Some patients have more difficulties with words, while yet others have more difficulties with pictures, and so on (Laatu, 2003). The deficits related to abstract and concrete concepts can be described as category-specific impairments. Category-specific impairments are those that affect certain categories of information, and are one of the most common types of semantic memory impairments (Garrard et al., 2001).

As mentioned earlier, semantic memory contains information and knowledge about the world, of objects, facts, concepts, features and words and their relations. Some of this information is of abstract kind, while other parts of the information are of concrete kind, and studies have shown that both abstract and concrete concepts may be selectively disrupted in semantic memory impairments. Therefore it seems possible that the information and knowledge of the abstract kind is differently organized in semantic memory, and in the brain, than is that of concrete kind (Laatu, 2003).

The difference between the two types of concepts is that concrete concepts are those that refer to tangible, observable, picturable and imaginable objects, such as “penguin” and “screwdriver”, while abstract concepts are those that refer to rather intangible, not readily observable or picturable entities, such as events, relationships, and abstract (non-material) objects. Examples of abstract concepts are “bachelor”, “crime”, and “comedy” (Laatu et al., 1997; Portin et al., 2000). The semantic memory deficits that I will describe in the following section are those related to concrete concepts. I will more specifically describe the most prominent type of category-specific impairments: the distinction between concepts referring to living and to nonliving things.

2.3.1.1. Living vs. nonliving things

The selective disruption of living and nonliving things is the most prominent type of category-specific impairments. Concepts referring to living things include for example animals, fruits, and vegetables, and concepts referring to nonliving things include man-made objects such as tools, furniture, kitchen utensils, and vehicles (Garrard et al., 2001).

Results from semantic memory tests have shown that patients with semantic memory deficits tend to have more difficulties with naming concepts in the category of living things than with naming concepts in the category of nonliving things. This pattern of impairments occurs both when visual and verbal stimuli are used to measure semantic knowledge (Warrington & Shallice, 1984). In these cases the ability to name nonliving things is not completely spared, but it is still much more preserved than the ability to name concepts in the category of living things. This pattern does not apply to all patients though, since there are cases of patients who have more difficulties with naming nonliving things than naming living things (Saffran & Schwartz, 1994).

This discrepancy has lead to the hypothesis that the information of living things must be more sensitive to damage than the information of nonliving things (Warrington & Shallice, 1984; Saffran & Schwartz, 1994), and there are two explanations for this. According to the first explanation, information about living, as opposed to nonliving, things are organized differently in semantic memory, and thus also located in different parts of the brain. Because of this, brain damage in different locations of the brain would cause different types of semantic memory deficits (Garrard et al., 2001). Evidence against this explanation comes from a few types of concepts that do not respect the living/nonliving dichotomy. Body parts, for example, are one type of these concepts. Musical instruments are another. Even though body parts are, apparently, living things, they seem to follow the pattern of nonliving things. Musical instruments are man-made objects, but their representation still seems to be impaired together with the representation of living things (Saffran & Schwartz, 1994).

The second explanation concerns the smallest units of meaning: the semantic features. According to this explanation it is not the organization of information in the brain that is crucial for the type of deficit. Instead it is the sensory and functional features that compose the information that matter (Garrard et al., 2001). All concrete concepts are composed of both sensory features, such as colour, shape, sound, taste, or smell, and functional features, such as what the referent of the concept does, or what it can be used for (Laatu, 2003). However, it seems that concepts in the category of living things are more dependent on sensory features than on functional features, while the opposite pattern seems to apply for concepts in the category of nonliving things. This can be seen in Figure 6. The sensory features seem to be more sensitive to damage, which would explain why concepts in the category of living things are more easily impaired. Support for this explanation is given from those categories that do not respect the living/nonliving dichotomy. Body parts, for example, have clear functional features while the sensory features of those concepts are less prominent (Garrard et al., 1997; Garrard et al., 2001).

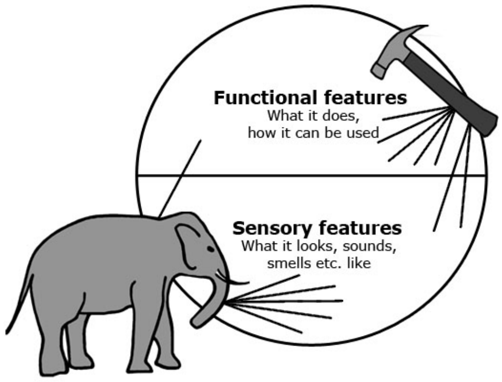

Figure 6. A model describing the representation of sensory and functional features among living and nonliving things. The semantic representations of living things seem to depend more on sensory than on functional features, while the opposite pattern seems to be the case for nonliving things.

2.4. Short descriptions of diseases in which semantic memory can be impaired

I will now briefly describe a few diseases in which semantic memory can be impaired, in order to give the reader a more complete idea of semantic memory deficits. Understanding these phenomena, and the context in which they occur, will help the reader to understand why semantic memory is difficult to study.

The diseases described in this section are Alzheimer's disease, Parkinson's disease, multiple sclerosis and semantic dementia. I will begin by describing Alzheimer's disease, since it is the most common cause of dementia, and a disease in which semantic memory deficits are accepted as a central part.

2.4.1. Alzheimer's disease

Alzheimer's disease (AD) is the most common cause of dementia in the elderly, mostly affecting people over 65 years of age. The prevalence rate is approximately six percent (Laatu, 2003), and the pathogenesis of the disease has remained unknown (Gazzaniga et al., 2002; Laatu, 2003). There is no known cure for AD (Banich, 2004).

In about 5 percent of the cases the cause of the disease is genetical (Gazzaniga et al., 2002). The neuropathological changes in brain tissue are characterized by neurofibrillary tangles (twisted pairs of helical filaments found within the neuron), amyloid plaques (conglomerations of proteins) and neuronal loss, and a diagnosis of definite AD requires a brain biopsy (Banich, 2004).

AD can be divided into several phases, and a rating scale is commonly used as a base for diagnosis. The scale ranges from 1 (normal adult) to 7 (severe AD), and describes what characterizes each stage of the disease (Banich, 2004). In the beginning of the disease the patient experiences diffuse and vague symptoms such as difficulties with memory, an impaired ability to learn new information, and difficulties with language (Laatu, 2003; Garrard et al., 2005). Later on, visuospatial deficits and worsened difficulties with memory become more prominent. Late in the disease the patient becomes more demented and language comprehension fails. The patient also has difficulties managing on his/her own, since recognizing and using common objects becomes more difficult. This includes difficulties with everyday tasks such as dressing and eating (Banich, 2004).

Studies have shown that AD patients are impaired on tests measuring semantic memory, and semantic memory impairments are today accepted as one of the central symptoms in AD (Hodges et al., 1992; Laatu et al., 1997; Laatu, 2003).

2.4.2. Semantic dementia

Semantic dementia (SD) is caused by damage to the temporal lobes of the brain, and is a type of frontotemporal dementia (FTD). FTD is caused by damage to either the temporal lobes, which causes mainly language specific symptoms, or to the frontal lobe, which mainly causes behavioural symptoms. Examples of other types of FTD are Pick’s disease and progressive aphasia (AFTD: The Association for Frontotemporal Dementias, 2007).

Frontotemporal dementia starts between the ages of 21 and 80 years, but is most common to start between 50 and 60 years of age, and it has been estimated that 4-20 percent of patients in memory disorder clinics suffer from some type of FTD. The general pathology for FTD includes atrophy or shrinkage of the frontal and temporal lobes, neuronal loss, and gliosis (the process of fluid and new capillaries filling the empty spaces of decomposed cells, until only glial cells remain (Banich, 2004)). There is no known cure for frontotemporal dementias (AFTD, 2007).

Semantic dementia is defined as a selective impairment of semantic memory, in the context of relative sparing of episodic memory and other cognitive functions (Saffran & Schwartz, 1994), and is thus different from diseases such as Alzheimer’s disease and Parkinson’s disease. SD is characterized by symptoms such as difficulties with understanding and finding words, a diminished understanding of general knowledge, and difficulties recognizing objects (Saffran & Schwartz, 1994; Garrard et al., 1997). Symptoms other than those related to semantic memory are uncommon, but behavioural, cognitive, or neurological symptoms, such as hyperactivity, personality changes, trouble with planning and with solving problems, and movement dysfunctions similar to those seen in Parkinson’s disease, may develop in some patients in later stages of the disease (AFTD, 2007). The speech of SD patients is fluent, and grammatically and phonologically correct, but is empty of meaning because of the word finding difficulties (Garrard et al., 1997; Kopelman, 2002).

2.4.3. Parkinson's disease

Parkinson's disease (PD) is a degenerative disorder which begins between 40 and 70 years of age, but there have also been cases of younger population suffering from the disease (Gazzaniga et al., 2002). The prevalence rate is approximately one percent over the age of 60 (Laatu, 2003). There is no cure for PD today, but the symptoms can be treated. The goal of treatment is to prevent degeneration of substantia nigra neurons and to enhance transmission at the dopamine synapse (Banich, 2004).

The pathogenesis of PD has remained unknown, though in some cases the cause of PD has been genetical. PD in younger population is known to be caused by drugs. The disease is characterized by loss of dopaminergic fibers from the substantia nigra to the basal ganglia (Gazzaniga et al., 2002; Banich, 2004), and the level of dopamine is markedly diminished (Portin et al., 2000).

Parkinson's disease is characterized by positive and negative symptoms. Positive symptoms are motor disorders that heighten muscular activity, and include resting tremor (rapid shaking) and rigidity. Negative symptoms are motor disorders that diminish muscular activity, and include disorders of posture and locomotion, hypokinesia (reduction of voluntary movement) and bradykinesia (slowness of movement) (Gazzaniga et al., 2002).

As the disease progresses dementia may become more prevalent and severe. It is common that patients suffer from difficulties with memory. Most often it is the effort-demanding memory and spontaneous recall that is affected (Laatu, 2003). Some patients also suffer from slow thinking (bradyphrenia) which can result in long silences before answering questions. Other symptoms are difficulties with concentration, and visuospatial difficulties which lead to problems with everyday tasks, such as dressing (Parkinson's Disease Foundation, 2003). There is evidence from semantic processing tasks suggesting that semantic memory deficits might be a part of PD (Portin et al., 2000).

2.4.4. Multiple sclerosis

Multiple sclerosis (MS) is a chronic inflammatory disorder which starts between the ages of 10 and 60 years, but is most common to start between 20 and 40 years of age. The pathogenesis of the disease is unclear (Laatu, 2003), and the prevalence rate varies with geographic latitude, being less common close to the equator, than to the poles. There is no known cure for MS today (Banich, 2004).

Multiple sclerosis is caused by demyelination of the axonal white matter in the central and/or peripheral nervous system, which results in a significant disruption in neural processing (Gazzaniga et al., 2002; Banich, 2004), and involves the white matter of the cerebral hemispheres, brainstem, optic nerves, cerebellum and spinal cord. (Laatu, 2003)

There are many symptoms characterizing MS, as the symptoms depend on which axons are affected by demyelination (Laatu, 2003). The first signs of MS may be disturbances in sensation, or double vision (Gazzaniga et al., 2002), and the first attack, which lasts for about 4-5 weeks, may include limb weakness, sensory symptoms, optic neuritis, brain stem symptoms, or combinations of these and other symptoms. The symptoms become more complex as the disease develops (Morrison, 2007).

Patients suffering from MS are known to have difficulties with memory, though not all patients suffer from these difficulties. When the disease progresses depression may develop (Banich, 2004), and patients may also suffer from other cognitive deficits such as impaired conceptual thinking and decreased speed of information processing (Laatu, 2003). Semantic memory tests show that semantic memory may be impaired in MS (Laatu, Hämäläinen, Revonsuo, Portin & Ruutiainen, 1999).

3. How to test semantic memory

In the first part of this essay, I have described semantic memory and some of the theories that provides an explanation for how it is related to other types of memory, and for how semantic knowledge might be organized within the memory system. I have also described some deficits of semantic memory. In this second part I will present some of the most important tests that can be used to study semantic memory.

3.1. Short descriptions of different tests

There are several different tests today that are used to study semantic memory, both in the clinical neuropsychological examination of patients, and in scientific research. One reason for this is that there is no single theory of semantic memory that has been accepted by all researchers. Another reason is that there is no single test that can be used to measure all aspects of semantic memory (Laatu, 2003).

There are several reasons why it is important to study semantic memory with different types of tests. A combination of tests can provide for a wider knowledge of semantic memory and its impairments (Adrados, Labra, Bernados & Moreno, 2001). Since there are a number of cognitive and physical factors that may affect the patient's performance on different tests, there is a risk that the results might become misleading. A wide range of tests reduces this risk (Laatu, 2003). Furthermore, when using different types of tests, it is possible to evaluate the different cognitive models of semantic memory. This is important in order to develop a correct model of semantic memory (Garrard et al., 2001).

3.1.1. Semantic priming

Semantic priming is a test that measures the subject's reaction time when presented a word or a nonword on a computer screen. In the most typical form of the semantic priming test, the subject is first shown a single word on the computer screen. This word is called the prime, and is shown on the screen for a short time, usually a few hundred milliseconds. The prime is then followed by a short delay, before a target word is shown on the screen. The target is also shown for a few hundred milliseconds, and is composed of a string of letters, that either forms a word or a nonword. For example, if the prime is the word “doctor”, then the target could, for example, be the word “nurse”, or the word “bread”. It could also be a nonword such as “nrseu”. When both the prime and the target have been presented to the subject, he or she has to decide whether the target word is a real word or a nonword.

The results have shown that if the target word is semantically or associatively related to the prime, for example when “doctor” is followed by “nurse”, the subject responds more quickly than when the target word is unrelated to the prime, as in “doctor” – “bread”. This is called the priming effect. The classical network theory provides an explanation for how this is possible. According to this theory, the names of concepts are stored as nodes in the lexical network. These nodes are connected to each other, and the more two concepts have in common, the more connections there are between them. When the prime word is presented to the subject, it will activate the node of that concept. This activation will then spread to the semantic network and activate related concepts. If the target word is semantically or associatively related to the prime word it has already been activated by this spreading. Thus it is allowed to be processed faster than a word that is unrelated to the prime. (Koivisto, 1999).

3.1.2. Category fluency

The category fluency task is a simple test that measures the subject’s capacity to generate words belonging to a specific category, for example the category of animals. When tested, the subject is given the instruction “I will now ask you to say out loud as many words as possible from a given category. Please tell me as many different kinds of animals as you can remember. You have one minute. The time starts now.” The correct answers generated by the subject are then scored by the experimenter. This type of test measures both verbal fluency and knowledge of different categories, and gives the experimenter an idea of how capable the subject is of producing words from different semantic categories, and thus of how extensive the impairment of semantic memory is. Category fluency tasks may also give an idea of how knowledge in the semantic memory might be organized in general (Adrados et al., 2001).

As can be seen in Table 1 below, the mean score of healthy controls in the test was 19.7 in the category of animals, while the mean score for AD patients was 9.9 in the same category. This means, that during one minute of time, a healthy control subject may generate around 20 different examples of animals, while the AD patient generates only half as many. A similar pattern is to be seen in the other categories (Hodges et al., 1992).

Table 1. Performance on the category fluency tests (Hodges et al., 1992).

	Controls *n=26*		AD patients *n=22*	
	Mean no.	SD	Mean no.	SD
Fluency: items correct				
Animals	19.7	4.5	9.9	4.1***
Birds	14.1	4.5	5.4	2.8***
Sea/water creatures	13.0	3.6	4.4	2.6***
Dogs	10.2	4.1	3.2	2.0***
Household items	19.8	5.7	9.1	3.8***
Vehicles	13.9	4.8	6.9	3.0***
Musical instruments	14.0	3.8	6.5	2.6***
Boats	11.6	3.4	4.4	2.9***

***Significant group difference at $P<0.001$.

3.1.3. Picture naming

The picture naming task is a test that has been commonly used to study semantic memory, and appears in several forms. The Boston Naming Task is one of these, and contains 60 pictures (Hawkins & Bender, 2002), while the picture naming task described by Adrados and colleagues (2001) consists of 36 pictures. These 36 pictures are divided into six different semantic categories, with six items in each category. The semantic categories represented in the test are animals, fruit, plants, vehicles, furniture and clothing. Another picture naming task contains 48 pictures, and results obtained with that test are shown in Table 2 below. The results show that the total mean score of healthy controls is significantly higher than the total mean score of AD patients (Hodges et al., 1992).

The picture naming task is known to be sensitive to linguistic and conceptual difficulties, and aims to trace the process of getting access to, and retrieving information from, semantic memory. Although sensitive to linguistic and conceptual difficulties, it can not be said with any certainty whether the subject's difficulties with finding the words required for naming the pictures are due to anomia or to semantic memory deficits. Anomia is a lexical deficit that is characterized by difficulties naming objects because of word finding difficulties, and differs thus from semantic memory deficits which are caused by damage to the semantic memory system (Adrados et al., 2001).

Table 2. Performance on the naming test (Hodges et al., 1992).

	Controls *n=26*		AD patients *n=22*	
	Mean no.	SD	Mean no.	SD
Naming				
Total correct (48)	46.4	1.1	35.3	8.9***
(1) Living items (24)	23.3	0.7	17.1	4.9***
Land animals (12)	11.6	0.5	8.3	2.8***
Sea creatures (6)	5.9	0.3	4.1	1.6***
Birds (6)	5.8	0.5	4.7	1.3***
(2) Manmade items (24)	23.2	0.8	18.3	4.8***
Household items (12)	11.9	0.3	9.7	2.4***
Vehicles (6)	6.0	0.1	4.9	1.6***
Musical instruments (6)	5.1	0.7	3.7	1.3***

***Significant group difference at $P<0.001$.

3.1.4. Conceptual hierarchies

The conceptual hierarchies task is a test that measures the subject's understanding of the relations within different conceptual domains. The test contains eight different hierarchies, of which four are composed of abstract concepts, and the other four of concrete concepts. Each one of the hierarchies contains ten items, as has been shown in Figure 2. Each hierarchy has a superordinate concept on top (e.g. "food") which is then followed by three subordinate concepts in the middle (e.g. “fruit”, “rootcrop”, and “vegetable”), and at the bottom of the hierarchy, there are two individual exemplars to each of the three subcategories (e.g. “lemon” and “pear” in the subcategory of fruit).

The test is divided into two parts, both containing four hierarchies. In the first part of the test, the subject is shown hierarchies that have already been organized, although some of the cards have been misplaced. The subject is then supposed to find the misplaced cards in each conceptual hierarchy and correct them. In the second part of the test, the subject is supposed to assemble the remaining hierarchies by his/her own. Results show that AD patients perform significantly worse than healthy control subjects on this type of tests (Laatu et al., 1997). Table 3 below show the results obtained by Laatu and colleagues (1997).

Table 3. Performance in the conceptual hierarchies task (Laatu et al., 1997).

Task variables	Controls	AD group	p-value
	Mean (SE)	Mean (SE)	
Total scores (max points 62)	58.9 (4.1)	36.1 (4.1)	0.002
Error recognition (max points 22)	15.2 (1.4)	11.1 (1.4)	0.080
Correct replacements (max points 22)	21.7 (1.3)	14.0 (1.3)	0.002
Construction of whole hierarchies (max points 40)	37.2 (2.9)	22.2 (2.9)	0.004
Construction of concrete hierarchies (max points 31)	30.2 (2.2)	18.9 (2.2)	0.004
Construction of abstract hierarchies (max points 31)	28.7 (2.1)	17.2 (2.1)	0.003

3.2. The Description of concrete concepts as a new test of semantic memory

In order to show that semantic memory is a very complex cognitive system that is difficult to study with the neuropsychological methods available today, I have described different theories, deficits, and tests. In this section I will describe a new theoretical framework of semantic memory which is presented by Laatu and her colleagues (1997). I will also describe a new test that has been designed with this theoretical framework in mind. The aim of this new framework is to make semantic memory easier to describe and understand, by dividing it into different levels of organization. This division would also help researchers to use the right methods when studying semantic memory (Laatu, 2003).

The tests described in the previous section are the most commonly used in the neuropsychological study of semantic memory. However, they only measure semantic memory functions indirectly. They provide us with information only about some levels of semantic memory, and do not measure the patient’s ability to consciously understand the meaning of the concepts (Laatu et al., 1999). Therefore there has been a need for a new type of test that would measure semantic memory directly. In order to achieve this, Laatu and her colleagues (2003) have developed a test in which spontaneous descriptions of concepts, and conscious analyses of concept relations, are used as a measure.

The main goal of developing this new test was to create a testing procedure that would capture the maximum performance of the patients, with a test that would be comfortable for the patients to perform (Laatu, 2003). In order to find out whether the patient is still able to consciously access the semantic knowledge needed, and if he or she is still able to understand the meaning of the semantic relationships between the concepts, verbal reports are used. There are several advantages with verbal reports. When a patient is given the opportunity to spontaneously describe a concept, no physical efforts, such as pressing keys etc., are required from the patient. Verbal reports also require a direct search in the semantic field of a certain concept (Laatu et al., 1997; Laatu et al., 1999; Laatu, 2003). The limitations of this method are related to cognitive factors, such as difficulties giving linguistic descriptions and making decisions (Laatu, 2003).

To be able to capture the maximum performance of the patient, no time limits are given to the subject in any of the three question levels of the test. Neither does the subject need to produce predetermined words or sentences in order to express intact semantic knowledge of the concepts. Instead the subject is allowed to use both circumlocutions and nonverbal expressions when appropriate (Portin et al., 2000; Laatu, 2003). In an attempt to assure that the patient finds all the knowledge he or she has about a specific concept, and to give insight into the access versus storage problem, cueing is used in the test (Laatu et al., 1999; Laatu, 2003).

3.2.1. The theoretical model behind the test

The theoretical model behind the test is provided by a three-level model of conceptual knowledge. This model suggests that semantic memory is organized into three different levels of information, which are the lexical level, the level of structural organization of semantic knowledge, and the level of conscious understanding. Each of these levels can be studied with different methods. For example, the lexical level can be examined with semantic priming tasks, while the test concerned in this section examines the levels of structural organization and conscious understanding (Laatu, 2003).

Figure 7 below represents the theoretical framework of the three-level model of conceptual knowledge. Although the figure is from 2003 the same ideas have been previously presented by Revonsuo (1993). As can be seen in the figure, the three different levels are marked with circles. The lexical level is found in the middle, and is surrounded by the level of structural organization. These two levels together construct the semantic memory store, to which words and pictures have different access routes. On top is the level of conscious understanding (Laatu, 2003).

The three-level model of conceptual knowledge suggests that when a word is presented to a subject, the lexical level becomes activated first. The lexical level is considered presemantic, and is the lowest level of conceptual information. It is considered presemantic, since at this level only the automatic associations between the lexical representations of the concept names are included (Laatu et al., 1997; Laatu et al., 1999; Laatu, 2003), which means that only phonological information of concepts is represented. This is why the word "strawberry" in the figure, would at this level, only activate phonologically related words, such as the word "straw", and no semantic understanding of the word would occur (Revonsuo, 1993).

At the level of structural organization of semantic knowledge, the multimodal associations that designate the meaning of the concept are activated. Multimodal associations refer to all the words, information, and features that are semantically related to the concept (Laatu et al., 1997; Laatu et al., 1999; Laatu, 2003). Thus the word "strawberry" would activate the words "blueberry" and "cranberry" among other berries, as well as information about the shape and colour, the superordinate connections to the word, and so on. A semantic network for the presented word is thus activated at this level, although there is still no true semantic understanding of the concept, since the represented relations are those between words, and no relations between the words and the experienced world are included (Revonsuo, 1993). It is first at the level of conscious understanding that the structural knowledge of the concept can be semantically understood (Laatu et al., 1997; Laatu et al., 1999; Laatu, 2003), since at this level, the presented word will be sent to other networks, such as episodic memory and object recognition, which activates related knowledge and experiences that puts the word into a context, which is crucial for the understanding of the concept. The word "strawberry" would at this level activate the information that strawberries are often eaten with whipped cream, and perhaps some personal memories that include strawberries (Revonsuo, 1993).

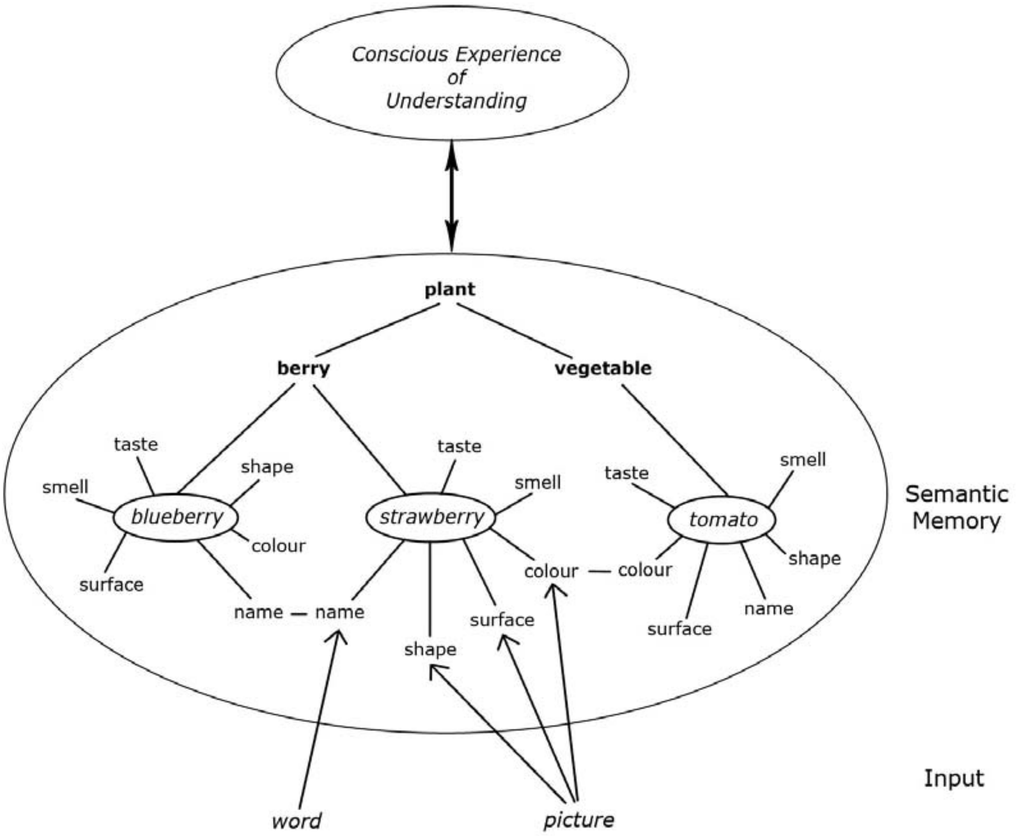

Figure 7. The theoretical framework of the three-level model of conceptual knowledge (Laatu, 2003).

3.2.2. Description of concrete concepts

Description of concrete concepts is a test that consists of fifteen different concepts. These fifteen concepts refer to living as well as to nonliving things, such as “penguin”, “peach”, “harp” and “sandbox” (Laatu et al., 1997), and all of the concepts in the test have been chosen for their unambiguity. This means that each one of the concepts only has one single concrete meaning (Laatu et al., 1997; Laatu, 2003).

Each of the concepts in the test belongs to a single and obvious superordinate category. Every one of these superordinate categories is different from the others, and the superordinate categories for the four concepts mentioned above are “bird”, “fruit”, “musical instrument”, and “a place to play” respectively. Each of the concepts also has at least two obvious structural features, and at least one obvious functional feature. Structural features are those that describe the concept, for example by shape, colour, size, location, or material, while functional features describe how things behave and can be used. The test as a whole contains 15 superordinate categories, 44 structural features, and 19 functional features, and thus there are a total of 78 items that are separately scored. As an example of these, the concept “penguin” has the following features: it is a bird (superordinate category), it is black and white, and has small wings (structural features), it walks upright, dives, and eats fish (functional features) (Laatu et al., 1997).

In the test, concrete concepts are tested at three different question levels, and the function of these question levels is to help the subject to retrieve as much information as possible from semantic memory. The first question level measures the subject’s ability to spontaneously generate information about the concrete concepts. In this level, the experimenter asks general questions such as “What is a penguin?”, and the subject is instructed to answer these questions as accurately as possible, without any aid from the experimenter. The more information the subject can produce about the concepts at this level, the more intact is the semantic memory. Every expected feature generated at this question level score three points, and thus 3x78=234 is the total amount of points in the test (Laatu et al., 1997).

If the subject can not spontaneously mention all of the expected features of the given concept, the experimenter will start to ask more specific questions, in order to help the subject recall the information needed. When the experimenter has started to guide the subject the total amount of points can not be received. Examples of questions at this level are “What colour is a penguin?” and “What kind of wings does a penguin have?”. Each correct answer to a specific question at this level scores two points. If the subject is unable to fully describe the given concept at the second level, the experimenter will ask forced-choice questions such as

"Is a penguin black and yellow or black and white?" in order to help the subject even more. Each correct answer at this level scores one point (Laatu et al., 1997).

3.2.3. Results

This test has been used in three studies of cognitively deteriorated patients (Laatu et al., 1997; Laatu et al., 1999; Portin et al., 2000). The results from these studies show that even though the degree of impairment varies individually, both Alzheimer's, Parkinson's, and multiple sclerosis patients suffer from semantic memory impairments. The results show that the patients had more difficulties than normal controls in producing the superordinate categories, as well as the structural and functional features of the concepts. The researchers noticed that the patients produced less correct answers during spontaneous recall, and that they needed more cues in order to describe the concepts. The patients also tended to make more wrong choices at the forced-choice question level. Table 4 below shows the results of AD patients in one of the studies. The results of PD and MS patients were similar to these. It should be mentioned, however, that there is a possibility that these results are caused by other difficulties related to the diseases and not by an actual impairment of semantic memory.

Table 4. Performance on the description of concrete concepts test (Laatu et al., 1997).

Description of concrete concepts	Controls	AD group	p-value
	Mean (SD)	Mean (SD)	
Superordinate categories (max points 45)	41.6 (2.5)	34.1 (9.3)	<0.001
Structural attributes (max points 132)	112.6 (9.9)	84.9 (26.2)	<0.001
Functional attributes (max points 57)	51.1 (3.6)	42.9 (12.7)	0.010
Incorrect answers	2.0 (1.9)	10.7 (8.7)	<0.001
Number of questions needed	29.0 (8.8)	45.7 (11.4)	<0.001
Wrong choices on the forced-choice level	1.9 (2.2)	11.3 (15.9)	0.015

4. Discussion

In this essay I have discussed semantic memory and its neuropsychological deficits. In order to grasp the whole phenomenon, I presented different theories, together with some diseases in which semantic memory may be impaired, as well as the most commonly used tests. Then I presented a new neuropsychological test, description of concrete concepts, and described both the theoretical framework of the test, and some of the results obtained. Together all these different aspects describe the complexity of semantic memory, which is the aim of this essay.

One of the most discussed problems of semantic memory deficits is the one concerning whether the impairments are caused by an access deficit or by a storage deficit. Laatu and her colleagues have kept this problem in mind while developing their test, description of concrete concepts, and aim to give insight into the problem. In order to do this, cueing is used. The idea of the test is to help the patients to retrieve as much information as possible about the concepts. Laatu and her colleagues interpreted the amount of external guidance needed to consciously access the information in terms of an access deficit, while the quality of the retrieved information was interpreted in terms of a possible storage deficit. Thus the results are indicating that semantic memory impairments are caused both by an access deficit and by a storage deficit (Laatu et al., 1997).

As previously described, description of concrete concepts is a test that consists of fifteen concepts, which are supposed to be described by the patients. Laatu and her colleagues collected these concepts on the basis of their unambiguity, and only those concepts that were known by all subjects in the pilot study were chosen for the test (Laatu et al., 1997). However, not all of the concepts used in the test are very common, and even though subjects in a pilot study are able to describe them, it should not be assumed that cognitively deteriorated patients are able to that as well. Laatu and her colleagues do explain that since the original version of the test is in Finnish, some of the translations in the article may only be approximate (Laatu et al., 1997). Although it is obvious that in different cultures different concepts are more common, which should be taken into consideration when developing these types of tests, the difference between the Finnish and the Swedish culture can not be that big. Laatu and her colleagues have, however, realized that the concepts used in the test might not be the best ones to use, and a new version of the test is currently under construction. The aim is to develop it into a relatively brief but sensitive test that detects semantic memory impairments through the task of defining concrete concepts.

Another problem might arise since the patients are allowed to use both circumlocutions and nonverbal expressions to describe the concepts when appropriate. When using nonverbal expressions the environment can be used as a guide for finding the answers needed. Although it is a positive sign that the patients are able to use cues in the environment to retrieve the semantic knowledge needed, it is possible that not all patients will do the test under the same conditions. The environment in which the test is done can not help the patients to retrieve all the semantic knowledge needed, but information about shape, size and colour might still be provided for. Only if some patients have access to more cues in the environment than others, a problem may arise. If this happens, then the results of the patients who do not have access to the same cues could become misleading. Thus, the environmental cues should be controlled as far as possible, although this problem might be difficult to solve entirely.

Semantic memory is a complex aspect of memory, and because of this there are several types of theories and models that concern its function and structure. The different models and tests that I have described in this essay concern different aspects of semantic memory. However, they do not seem to contradict each other to any major degree, nor do they seem to describe semantic memory differently. Therefore it seems as we are on our way towards a more complete understanding of how semantic memory is organized and how it functions.

Since semantic memory deficits have not been accepted as a part of most neurological diseases until recently, there has not been any need for neuropsychological tests that can be used to study semantic memory. The most commonly used neuropsychological tests available today only measure semantic memory indirectly, and do not capture the phenomenon completely. Therefore there is a growing need for new tests. The test, description of concrete concepts, could be a good start to achieve this.

The conclusion I have come to is that semantic memory is a complex cognitive system that needs to be studied further, both with the neuropsychological tests that are available today, and with new neuropsychological tests in the future.

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