EFFECTS OF HAPTIC REHEARSAL ON SELF-CORRECTION OF LETTER AND NUMERAL SHAPE REVERSALS, INVERSIONS, TRANSPOSITIONS AND SUBSTITUTIONS

BY

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FACULTY OF GRADUATE STUDIES
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BY

Linda C. Dewick

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree

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ABSTRACT

Early years pre-logical students with literacy development difficulties, may have have failed to develop accesss to, or control of a spatial orientation device, the virtual gyrostatic mechanism (VGM), a phenomenological device which may operate within holographic memory. Within the construct of the neural hologram are properties which may account for the existence of a VGM. This study examines the effects of haptic rehearsal strategies on the manipulation of holographic forms of memory storage and retrieval. This instructional strategy is intended to help students develop the ability to ameliorate orientation incongruencies, such as the reversal and inversion of letters and numerals, for the purpose of improving literacy skills. It is hypothesized that self-correcting tendancies, for letters and numerals may develop when students gain control of the VGM, and that access to and control of the VGM may occur by using haptic rehearsal strategies with three-dimensional objects. The purpose of the study is to see if students can be assisted to develop self-correcting tendencies for letter, numeral and shape errors by looking at photographs showing the front, back, top, bottom and side views of objects, identifying the views, and matching the views with concrete stimuli. When required students will be given hand-over-hand physical assistance by the researcher to match the two-dimensional photographic stimuli.

Twenty subjects aged 7 or 8 years in Gr.2 or Gr.3 were assigned to two groups. Group #1 included 10 students who showed letter or numeral reversals, inversions, transpositions or substitutions in their written work and who had early reading difficulties. Group #2 included 10 students with few written work errors and with strong early reading skills. A 15 minute screen of pre-literacy skills was used to determine group assignment. A 23 minute pre-test of literacy skills was administered. The students in both groups recieved three 15 minute treatment sessions in which they (a) looked at photographs of stuffed toys, wooden letters, and numerals in a variety of positions, (b) identified the views of the objects in each position, (c) repeated the positions with the concrete objects, and then, (d) matched the objects to the photographs. A 27 minute post-test of literacy skills concluded the study. Statistical analyses were conducted using the Wilcoxon Matched-Pairs Signed-Ranks Test(alpha=.05) for within group pre to post-test comparisons and the Kilmorogov-Smirnov Two Sample Test(alpha=.05) for between group comparisons pre and post-test. A statistically significant difference between Group #1 and Group #2 on a literacy skills pre-test confirmed that the two groups were, as anticipated, different at the outset. As expected the strong early reading skills group (#2) did not show a statistically or educationally significant improvement as a result of the haptic rehearsal. However Group #1 showed significant educational improvement on a literacy skills post-test but not enough to reach statistical significance. These results suggest that further research into haptic rehearsal may yield further insights into how we might better help early years students who make letter and numeral reversals, inversions, transpositions, and substitutions to learn to read at the same pace as their more able peers.

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CHAPTER I

Introduction

Brain theory research spanning centuries has produced a multitude of facts which reveal, to some extent, how the human brain functions in learning and memory. This field of inquiry is advancing rapidly due to the development of technologies that can scan and map the brain's functions. According to Brierley (1994), this data needs to be analyzed by a "Darwinian mind" in a master stroke of genius to produce the foundational theory for the next generation of brain function studies. Brierley states that a sound theory of brain functions will benefit educators because it will assist teachers with a clearer understanding of how children learn to read, how to teach reading, and how to ameliorate the difficulties learners face with analyzing sight, sound, and touch stimulation in learning environments.

Statement of the Problem

This research explored one possible educational implication of the phenomena of electrical impulse transmission at the junctural sites of the neural *ganglia* along the *geniculo-striate pathway* (optic nerve to the visual cortex, see Figure 1) in the context of holographic memory theory (Pribram, 1971; van Heerden, 1970; Garbor, D. 1946). This researcher suggested that there exists a *virtual gyrostatic mechanism* (VGM) responsible for *visual spatial orientation* which can be observed to not yet be under the control of pre-logical early years students.

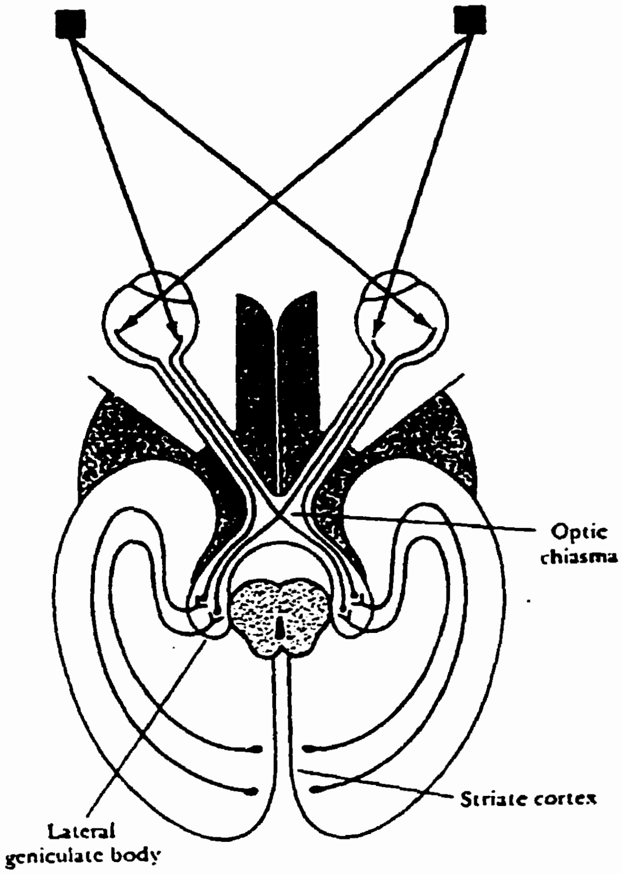


Figure 1. Brown's (1976) Schematic representation of the neural pathway involved in vision. The bioelectric impulses generate in the retina are conducted by the optic cranial nerve to a site known as the lateral geniculate body. Here, complex synaptic connections result in the retinal impulses being subjected to various excitatory and inhibitory influences and to intensify changes which bring about further coding. The impulses are then conducted to the visual cortex in the striate area of the occipital lobe, where still further and even more complex coding occurs.
[From Brown, 1976.]

It was proposed that selected tasks utilizing *haptic enhancers* may facilitate the exploration, invention, and experimentation of VGM control by early years subjects. Gaining access to the VGM and exercising control over its function may result in improved performance in school related *literacy performance skills*. Methods of visual rehearsal during *encoding*, while not yet specified by prior researchers (Spoehr & Lehmkhule, 1982), are proposed to take the form of haptic enhancers. By means of the VGM hypothesis, the author attempted to explain one of the *missing links* in the constructivist learning theories of the 20th century, by specifying how the visual encoding and transformation of stimuli may occur in short and long term memory in the context of early reading literacy skills.

Purpose of the Study

This study pusued a hypothetical memory engram which may explain one of the missing links in current learning theory. In particular, the failure of pre-logical early years students to master the singular perspective of letters, numerals, and shapes associated with orthographic systems such as writing, spelling, and the printed form.

In this study, memory was viewed as a process rather than an event. It was proposed that memory may be situated on a continuum of learning rather than as a separate brain function. Memory storage is assumed to be distributed throughout the nervous system at a molecular level.

The purpose of this study was to identify a procedure to activate a proposed spatial orientation mechanism, the virtual gyrostatic mechanism (VGM). When activated the VGM may be responsible for a phenomenological process of three-dimensional holographic storage and retrieval, which may assist learners to develop self correcting tendencies for letter, numeral and shape reversals, inversions, transpositions, and substitutions. Gaining control of perception through *visual/haptic-spatial orientation* procedures may facilitate the retention of information during short-term memory rehearsal and long term memory storage, resulting in improved *literacy skill performance.*

The VGM may be an aspect of holographic memory through which students may learn to self-correct transformations of two dimensional orthographic symbols into three dimensional representations which are stored as neural holograms and which may become thought, and eventually expression, when they print or interact.

Research Questions

Question #1: Is there evidence consistent with a virtual gyrostatic mechanism(VGM)?

Question #2: Is there evidence consistent with a lack of control of the VGM in pre-logical thinkers?

Question #3: Is there evidence the VGM can be brought under control by pre-logical thinkers?

Question #4: Is there evidence that having the VGM under the control of pre-logical thinkers can improve literary and numerary skills?

Background to the Problem

While much educational research has been conducted in the area of reading disabilities to address the problem of letter and numeral reversals, inversions, transpositions and substitutions, there remains no clear understanding of what causes these errors to occur or how to ameliorate them. Limited success has been achieved by encouraging students to use the uppercase form of the letters B and D to eliminate confusion, and metacognitive strategies such as b for bed where the correct formation of the letters b and d will create a schema of a bed with a head and footboard.

Rationale and Theoretical Framework

The outline for the proposed arguement proceeded as follows. The investigation of the human brain's ability to perform spatial orientation and mental rotation tasks began as early as 1910 and is supported by empirical studies, as an accepted phenomema of mental imagery. The holographic memory model (HMM) provides a suitable theoretical framework in which a neural holographic property can be introduced to account for some aspects of memory, in particular three dimensional shape and object recognition. The HMM is applicaple to visual input processing because of its reliance upon light wave transmission to form soft tissue holograms. The haptic enhancement of visual input may create holographic memories the spatial orientation of which which may be under the control of the VGM. Failure to develop control of the VGM may explain some learning problems encountered with reading, in particular the reversal, inversion, and transposition of letters and numerals. Haptic rehearsal during short-term and working memory encoding may result in developing control of the VGM. Once under control of the subject, the VGM may assist the subject to self-correct errors by reorienting the standard position of stimuli to create a match with the subject's internal view of symbols. The result may be an improvement on the subject's performance on literacy related tasks.

Research that attempts to learn more about the characteristics and behavior of children's holographic memory capabilities and their access to and control of their spatial orientation abilities possibly using the VGM is needed. The data gathered from such experiments may provide knowledge which may assist teachers to develop new instructional strategies for students with reading difficulties. The difficulties that early years students experience with beginning reading development skills persists despite the decades of research conducted to ameliorate these difficulties. There is a need for clinical studies with scientific research designs and sound methodology, to provide a more in-depth view of the neuropsychometric properties of memory. Current biomedical research technologies examine the hypothesis of holographic memory (HM), at a molecular level with animal subjects, including cats and monkeys. With the advent of computer technology, some day it may be possible to examine the VGM hypothesis within a virtual environment utilizing haptic interface, first with animal subjects and then with human subjects.

Human Brain Spatial Orientation/Mental Rotation Theories. Four hypotheses that examine the phenomena of human brain spatial orientation abilities with repect to mental rotation will be discussed. These include; Perkey's Effect, cortical mapping of imagery center, the mental rotator network, signature of mental rotation, and geon theory.

Cheves Perkey (1910), while conducting imagery experiments, determined that holding a mental image interferes with seeing faint and fine details. This phenomena, called Perky's Effect substantiates the belief that imagery affects perception. Kosslyn (1993), using Positron Emission Scanning (PET scanning), has identified the visual cortex as the center for imagery and has found that mental images may cause higher levels of activity in the visual cortex than actualy viewing something real. The idea of a mental rotator network has been proposed by Cooper and Shepard (1973), Tarr (1995), Tarr and Bulthoff (1995), Farah (1989), Finke, Pinker, and Tarr (1989) and Tarr and Pinker (1989). They found the *this side up* orientation of an object crucial to its identification during a process in which the subject brings the object into view by mentally rotating it a degree at a time until the correct match is achieved. Pinker (1997), states that "people can mentally rotate a shape into the upright and then recognize the rotated image" (p.275). He suggests that a mental image-rotator is available which may enable two and a half dimensional views, such as photographs to be stored from a variety of perspectives, so that an object which does not match one of the stored images can be mentally rotated until a match is found.

A signature of mental rotation was discovered when it was found that the greater the number of degrees that the image needed to be rotated the longer it took for the subjects to perform the task. Further, it was discovered that the human brain is capable of two and three dimensional visual thinking in which people rotate shapes in their minds in three ways; for simple shapes a 3-D geon model centered on its own axis is stored, a complicated shape is stored at each of the orientations it is viewed in, and at an unfamiliar orientation the shapes are rotated to a more familiar orientation.

Holographic Memory Model (HMM). Justification for selecting the *holographic memory model*(HMM) as the theoretical context for the VGM lies in (a) its inclusion of the storage of three-dimensional forms and (b) the increased capacity of the hologram to store the vast quantities of information available to recall which cannot be explained by electrical impulse transmission. The HMM is compatible with the proposed VGM because of the following hypotheses; that three-dimensional forms can be oriented through the use of concrete manipulatives within memory to create a match with the correct or desired form or orientation required for recognizing letter shapes and numerals, and that by enabling the learner to develop control over the VGM, self-correcting tendencies will develop which may improve performance on literacy related tasks. The unique three-dimensional aspect of the holograph storage and retrieval system provides a means by which the abstraction of concrete forms can be remembered. In this respect, the VGM may be a facet of the phenomena of HM.

It is widely accepted, in the field of cognitive psychology, that learning takes place which has not yet been accounted for by existing brain theory research. Two problems with current brain theory are relevant to the selection of a holographic memory model in this study. First, the implausability of acquiring the quantity of information the human brain has the capacity to process and store through conventional *electrical impulse transmission*. Second, the potential to expand the brain's storage density through *optical information storage systems* using *coherent light*, and *mechanical wave form* transmission to create *neural holograms*.

Within the *electrophysical information processing model,* the CNS has been shown to acquire information through electrical impulse transmission. Electrical impulses occur in response to stimuli called *bits,* which excite a response from the cells receiving them. It takes 1/18th of a second to differentiate between one group of seven bits and the next group of seven bits (Csikszentmihali, 1990). Therefore, the calculated rate at which this process occurs is, at most, 126 bits of information per second.

The ability to focus attention, attentional habits, and biological and social factors affect whether information enters consciousness. Attention is also required for remembering, thinking, feeling, and making decisions. Attention is defined as *psychic energy* (Csikszentmihalyi, 1990), an energy under human control. The processing capacity of the brain has, through the course of evolution of the nervous system become proficient at compressing stimuli in a process called chunking whereby the task becomes automated leaving the mind free to do other things. Additionally information is compressed through symbolic means, language, math, abstract concepts, and stylized narratives (Csikszentmihalyi, 1990). These phenomena alone cannot account for the extreme variability between individuals when explaining the brain's capacity to process information.

Holographic memory is based upon the use of a *neural holographic system* to store and retrieve vast amounts of information. Within this model of brain theory coherent light can be used to superimpose images at the same physical location in the *visual cortex* using different spatial frequencies (Pribram, 1971). Each image can be retrieved without being affected by the other images. The *holographic hypothesis* on *brain function* in perception takes the form of *superposition*. The brain aquires information through wave form transmission.

Within the HMM the brain's physical capacity to store information becomes vast. van Heerden(1968), has demonstrated that ten billion bits of information can be stored holographically in a cubic centimeter. It is estimated that between hundreds of millions and a billion neurons are electrically activated during each memory event with impulse conduction speeds of 360 to 400 km./hr. It is impossible to store the same amount of information electrically as holographically because of the rate of electrical impulse transmission. The optical storage and processing of information through the neural holographic process may provide a means of explaining how human memory works that is consistent with the diverse and complicated findings of memory research.

Application of HMM to Visual Input. The field of neurobiology clarified neuronal processes involved in information processing, storage, and retrieval. Methodologies from electrophysiology, and computer tomography assisted with this research. But the structural correlate to a memory storage event of visual impressions continues to be an unexplained phenomena of the human experience. According to Rahmann and Rahmann (1996) "we are still not in a position to understand all of the details of the immensely complex issue of information processing and storage, i.e., memory formation, in large part, because so many factors still stand in the way of researchers in their search for the engram" (p.264). For example, the exact location of memory within the NS is still unknown. In the 1990s the search for the memory engram continues. Rahmann and Rahmann (1996) explain the current presumption:

> "that the most likely repositories of memory are those locations in which the sensory impressions develop. The neuronal assemblies that exist beneath the cerebral cortex might serve as feedback pathways to the cortex as memory is being formed: the neuronal assemblies involved in memory must interact with the sensory areas of the cortex after a sensory impulse, having been processed already in the cerebral cortes, has stimulated the amygdala and hippocampus." (p.266)

The widely accepted view which prevails to date, of memory formation is that it occurs as a result of molecular changes in the synapses of the neuronal structures involved in perception, analysis, processing of learned information. There is also agreement that memory is stored in the CNS (brain and spinal cord) and not in either the sensory nor motor neuronal pathways.

Various research methods have been used to determine the brain structures involvement in memory storage. The prominent methods include animal studies in which lesions are caused in the CNS and then the effects of these lesions on memory-oriented tasks are observed, the measurement (using lead electrodes or by metabolic change) of neuronal activity in various brain regions before and after the administration of marker substances, and case studies in which human subjects have suffered damage, due to trauma in specific regions of the brain that has result in the loss of the ability to learn and recall. The results of this extensive experimental research indicate that while brain damage alters behavior by reducing the ability to perform memory-oriented and learning-oriented tasks, an isolated repository for memory storage cannot be identified. The distribution of memory among the many structures of the CNS is proposed. The neurons responsible for producing memory are believed to also be involved in memory storage. A view of memory as a synergistic activity where the total effect of the memory phenomenon is greater than the sum of the individual effects which cause it to occur, or that memory is a type of resonance or vibration which intensifies and enriched the interaction among neurons which results in a state of adjustment.

Lashley (1950) proposed two principles to account for the proportionate decreases in the ability to perform memory-oriented tasks in relationship to the mass of cortical removal. The first principle of mass action suggests that memory formation is dependent on the available brain substances and not upon specific brain regions. The second principle, or equipotentiality, describes the functional reciprocity among varoius brain regions. These early hypotheses remain accepted.

The largest portion of memory content is believed to result from visual sensory perceptions. As a result current experimental inquiry focusses upon the neuronal processesing pathways responsible for sight, or visual perception, and those brain structures that are believed to be involved in the depositing of memory content. The visual stimuli flow from the retina via the optic nerve to the lateral geniculate bodies in the diencephalon. Most of the neuronal pathways are relayed to the occipital region of the cerebral cortex, the area striata, where visual input is intially processed. In the area striata individual neurons respond to spatially defined elements within the field of vision such as clearly demarcated borders or colored dots. Other neuronal pathways project the input about properties of the stimulus such as general shape and color to other neurons situated along this pathway for analyses. This object-oriented pathway ends at the inferior temporal gyrus (gyrus temporalis inferior) where still other neurons transmit information about additional properties of the object including a broad section of the field of view. It is assumed that all of the information about the object collects at this location. It is assumed that a second projection pathway exists in the anterior parietal lobe that is involved in the processing of spatial relationships within a visual scene. This pathway for processing visual information may be reponsible for the memory formation of visual impressions, from the cerebral cortex into the lower lying brain regions and their underlying structures. This pathway was identified in surgical lesion studies with monkeys conducted to test visual recall. The results indicated that a visual perception materialized in the last section of the projection pathway, where the subparietal cortex stimulated two parallel neuronal assemblies, one that originates in the amygdaloid nucleus (nucleus amygdalae), and the second derives from the hippocampus. Both regions were found to be involved in properties of cognitive learning such as object recognition and the ability to recall from memory properties that are not being perceived at that moment and to attach emotional significance to those properites. It was concluded that these two regions did not represent the final location of the structures involved in visual perception and visual information storage as the projection pathway from these two regions to the striate body (corpus striatum) and to the diencephalon (thalamus and hypothalamus). In this way the circle of information processing closes as the neuronal pathways send the input back to the cerebral cortex (see Figure 2). It is also believed that the amygdala is involved in producing the emotions that accompany the processing of sensory stimulii. Reciprocity between the amygdala and cerebral cortex may explain why intense emotional experiences generate particularly long-lived memories.

Current research for the structural correlate to a memory storage event of visual impressions leads to the investigation of a reciprocal feedback mechanism between the neuronal representation centers in the cortex and the neural networks of the amygdala and hypocampus. Clearly, there is no single repository of memory in which memory storage is highly localized, refuting the theory of a single specified location for memory storage in the brain as was pusuant in the investigations of researchers through to the 1980s. Current evidence provides a basis from which to postulate a theory of memory as dispersed, where memory storage is distributed diffusely over the regions of the neural networks. The analogy of memory stored as individual reference points in a picture has shifted from that of a photograph to a hologram.

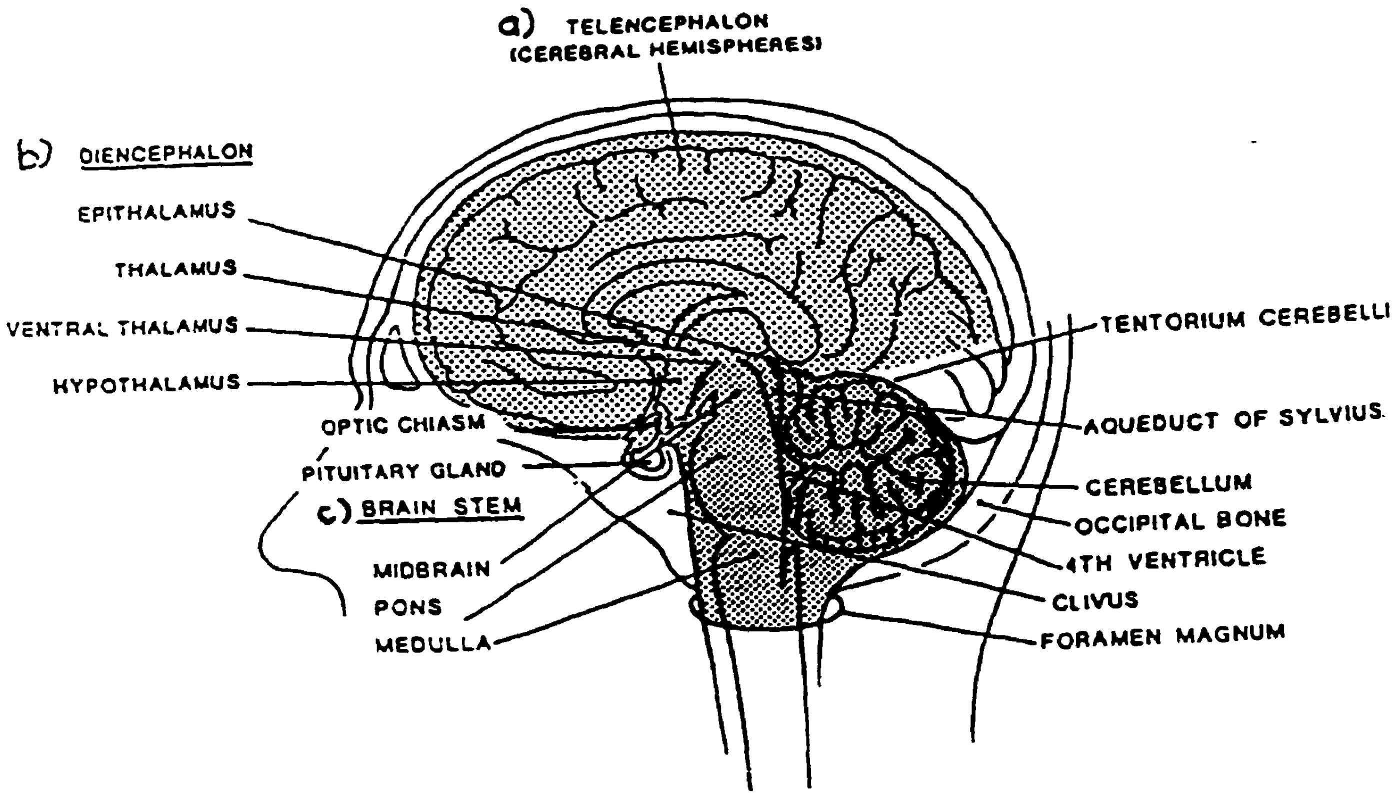


Figure 2. · Adaptation of Baugmgartner, J.M., and Bentley, W.H.'s (1989) reprinting of Daube and Sandok's (1978) diagram of the supratentorial level of the brain. The brain is divided into the telencephalon, diencephalon, mesensephalon, mentencephalon, and myelencephalon. Each is a horizontal level subdivided as specific structures at that level. The telencephalon (see Figure 2a) includes the paired cerebral hemispheres, including both cortex and white matter immediately deep to the cortex. It also includes the basal ganglia and the olfactory tract or central portion of the olfactory nerve which passes through the telencephalon. The diencephalon (see Figure 2b) is the major subdivision located deep into the telencephalon and is composed of deep midline structures and structures located at the base of the brain. Important diencephalon structures include the thalamus, hypothalamus, pituitary gland, and the central part of the optic nerve or optic tract. The diencephalon is continuous at its caudal end with the mesencephalon, or midbrain. Below this level is the metencephalon, which includes the cerebellum, pons, and cranial nerve nuclei. Lastly, the myelencephalon consists of the medulla oblongata and numerous cranial nerve nuclei. The medulla is bordered inferiorly by the spinal cord. Brainstem (see Figure 2c) refers collectively to the midbrain, pons and medulla. [From Baugmgartner and Bentley, 1989.]

Rahmann and Rahmann (1996) state; "individual memory inventories are stored not so much as the individual reference points of a photograph, but as of a hologram, whereby it is possible to store and recall three-dimensional spatial scenes" (p.267).

The phenomenon of memory can be described as a response of the neural circuits in the larger brain which function in response to stimuli to neural memory networks by means of molecular facilitation through feedback in the synapses. The developing patterns of neural networks are preserved and retain the perceptions which caused them to form. Recognition and recall results when the same group of neurons is stimulated with the same kind of sensory stimuli that intially established it. It then follows that, in the origin of new memory content, each new synapse will store a portion of the new information. In this way each new perception and the information garnered from it will be preserved within a diffuse neural network created by the formation of new synapses. The result according to Rahmann and Rahmann (1996) is that; "every individually acquired bit of information is stored within the nervous system in a diffuse manner, i.e., over wide areas while, at the same time, vast amounts of information can be layered in storage throughout the entire system" (p.267).

The testing of assumptions about the processing capabilities and capacity of short-term memory provide evidence that the ability to store information over the short-term is greater than the capacity (a span of seven plus or minus two items) to remember that stored information (Miller, 1956). An organizational process, *chunking* (Simon, 1974), is a system of recoding longer strings of items into shorter chunks, which has been shown to increase the short-term ability to remember more information (Shannon & Weaver, 1949). In this way a *chunk* is a functional unit of short-term memory. When one item of the unit it recalled there is a likelihood that the other items in the unit will be remembered with it (Bower, 1972; Bower & Wizenz, 1969; Chase & Simon, 1973; Shimp, 1976). Evidence for visual information chunking is reported in visual imagery studies for attack strategies in chess (Chase & Simon, 1973; Simon & Gilmartin, 1973) and for word lists retained by forming visual imagery referents of those words (Pavio & Begg, 1971; Pavio & Smythe, 1971; Pavio, 1975). While the antecedents of chunking have not been identified, chunks have also been shown to consist of linguistic (rhythm and syntax), and motoric information (Miller, 1956) It is easier to remember a number of items if they can be formed into a syllable or a word. In this way words are recalled with greater efficiency than are random strings of letters. Implicit in these findings is the need for future research to examine the causes of organizational phenomena in memory.

In this study it was proposed that holographic information may also be grouped or chunked during the process of the spectral transformation of a two-dimensional image into a holographic representation of that initial image, and that the chunking or grouping ability of HM may be regulated or enhanced by gaining access to and control of the VGM by using three-dimensional haptic enhancers to provide rehearsal for learning and memory formation and retrieval. Three-dimensional symbols (objects including stuffed toys, wooden letters, and numerals) are used as haptic enhancers to induce holographic chunking that may result in organizing and recoding information for long-term memory storage during short-term rehearsal. Subject control of the VGM may improve accessibility to memory during recall.

Haptic Enhancement to Create Holographic Memories

The proposal that haptic enhancement may be utilized to create holographic memories is based upon the folowing seven assumptions. First, developmentally, haptic memory represents the earliest form of memory where learning occurs through the sensorimotor experiences of touching and manipulating objects in the learner's environment to form haptic perception. The storage and retrieval of this sensory data occurs through physical interaction within the environment. As a result this input mode, because of its strong association with early learning and its use of concrete objects to form haptic perceptions is believed to be a basic form of intelligence, and one which remains of relative strength and accessibiity to early years students. It stands to reason then that if the goal in creating holographic memories is to assist the learner with recoding previously encoded stimuli to activate the VGM and to develop self-correcting tendencies to ameliorate their spatial orientation diffuculties with symbol recognition that the touching and manipulation of concrete objects may be a means by which this goal can be accomplished.

Second, the haptic perception formed through touch and kinesthesis provides feedback through the skin's sensory receptor cells when an object is manipulated. This feedback provides the alteration in the subject's awareness of the position of their body with respect to the object being perceived and manipulated. This may allow subjects to align their inner (or mind's eye) three-dimensional view of the object with the orientation adhered to within the symbolic systems used in reading, writing, and mathematics.

Third, haptic enhancers, in this case the three-dimensional symbols specified in the treatment conditions are manipulated by the subjects in specified procedures and may enable the subject to encode information on a third dimension beyond what is available through conventional two-dimensional pictoral representations of the same symbols which are commonly used as instructional stimuli in classroom instruction. The introduction of the third dimension to object recognition may activate the VGM. The subject may gain control of the VGM to create a match between their mind's eye perspective of the object and the singular orientation desirable in literacy skills.

Fourth, haptic rehearsal or the repetitive process whereby the subject manipulates three-dimensional objects or haptic enhancers encourages the subject to explore in an inventive and inquisitive manner without overt concern about the accuracy of his or her responses. The subject persists at task until he or she is satisfied with his or her response or self-correction and, in this way, the anxiety associated with previous repeated failure experiences may be alleviated. This researcher has witnessed early years students shed tears of frustration when informed by their tutors that the letters or numerals they have written are wrong, and are made to erase and redo their work only to repeat the same response taxing the patience of the tutor and increasing the frustration level of both student and instructor. The downward spiral of failure created by the teacher's insistence that the child view a stimulus from a singular perspective may be altered when the subject is given permission to adopt an inventive approach and may result in greater risk taking to create an upward spiral of success.

Fifth, haptic re-orientation, or the procedures by which the subject is guided verbally and physically to perform may result in achieving a match during haptic rehearsal between the subject's perception of the object and the singular perspective aknowledged in the printed form. It is this spatially re-oriented match achieved by exercising control over the VGM which may be input holographically to re-encode information about the object that will result in self-correcting tendancies during recall subsequent to the haptically rehearsed learning.

Sixth, holographic memories are believed to be a part of thinking. In the holographic memory model, thought is viewed as the search through holographic memory for the resolution of uncertainty. Holographic representations are associative mechanisms which instantaneously perform the cross-correlations attributed to thought in the problem solving process. Holograms are the catalysts of thought. Asssuming that haptic enhancement can induce holographic memories, then it seems reasonable that holograqphic remembering may be a form of memory suited to the recoding of information The cross-correlations of the associative mechanisms of HM may increase VGM control.

Finally, HM is viewed as a process or an event, and not as a repository of stored information. The VGM is proposed as a phenomenological event, a process by which the spatial orientation of visual/haptic stimuli may be controlled. Therefore the haptic enhancement utilized to create holographic memories may activate the VGM, to function in concert with the process of holographic memory storage and retreival.

VGM as Orientation Device. The VGM is a theoretical model of a spatial orientation device available to the subject which may be used to facilitate short-term and working or intermediate memory storage by manipulating holographic memory images created by haptic enhancement procedures. The proposition that a phenomonlogical spatial orientation device which governs the rotation of solid bodies, having effect but not form, such as the VGM, is based on the following three assumptions.

First, it is accepted that spatial orientation mechanisms exist in other species which are involved in animal navigation such as magnetic field detection, sonar, electrical field detection, wave motion detection, olafactory imprinting and infrared sensing. It is then reasonable to assume some form of spatial orientation mechanism may operate in the humans and may be involved in processes beyond those of survival.

Second, the question as to why letter and numeral reversals, inversions, transpositions, and substitutions persist beyond the early years remains unanswered. The failure to orient letters and numerals to the correct form adhered to within the language and symbolic systems used in reading, writing, and mathematics prevents learners from developing literacy skills. Some students achieve success in developing literacy skills while others do not and so some mechanism may operate to enable or prohibit learners from gaining a perspective of symbols which makes sense to them in the context of the printed form. Spatial orientation appears to be the key to recognizing symbolic forms. If orientation ability is increased by gaining control over the mechanism involved in orientation then it seems reasonable that individual symbol recognition may be improved and that this ability to ameliorate orientation incongruencies between the stimulus and the correct form may result in self-correcting tendancies to improve literacy skills.

Third, students who experienced success with the development of literacy skills are believed to be exercising control of the VGM and have been observed by this researcher to demonstrate the following behaviors; spontaneous self-correction of written or transcription errors, mental substitution of letters in words to create new words, verbally spelling their name backwards, recognizing upside down images, mirror reading of symbols and puzzle strategy based both on form and image. Students who experienced failure with their development of literacy skills were believed to not be exercising control of the VGM were observed by this researcher to fail to demonstrate the behaviors listed above. Therefore it is believed that the VGM may be responsible for the spatial orientation incongruencies between these two groups of students.

Learning Problems Explained by Failure to Develop VGM. Failure to develop control of the VGM may result in learning problems associated with low literacy skills performance. These include; the inability to develop the awareness of when an error in writing or transcription has been made, the reliance upon pictorally concrete stimuli to substitute letters in words to create new words, the inability to perform mental abstractions for verbal spelling, the reliance upon repositioning the body or stimulus physically to recognize inverted images, the inability to recognize mirror images of symbols, and the failure to develop a puzzle strategy relying instead upon a random trial-and-error approach to puzzle completion.

Haptic Rehearsal Develops Control of VGM. Control of the VGM may be developed through haptic rehearsal strategies which involve the concrete manipulation of symbols to provide tactile feedback to the subject about the form and orientation of the symbol. Tactile feedback is used to explore the environment and to achieve tactile identification of objects, positions, and orientations. Tactile feedback can also be used actively to manipulate or move an object to perform a task. The human haptic system has two sub-sytems, the motor and sensory sub-systems. The sensing of forces is motor/kinesthetic and is achieved by mechanorepceptors located in muscles, tendons, and joints. Sensory tactile sensing is achieved by mechanoreceptors located near the surface of the skin with the highest concentration found in the hands.

According to Smith (1998), two forms of haptic exploration are used by humans. Active haptic exploration occurs when the subject controls his/her own actions. Passive haptic exploration occurs when the hand of the subject is guided by someone else. Smith, C., (1998) cites studies, conducted by Kennedy, Gabias and Heller (1992), with blind subjects to compare the accuracy of active versus passive haptic exploration. Their results indicate that "when a subject's finger was guided around a two dimensional object, such as the profile of a swan, they were more likely to identify the objects [as compared to active haptic exploration]" (p.3). Smith, C., (1998) cites other studies conducted by Brooks and Batter (1971) and Brooks (1977) which used a computer simulation to present subjects with a multi-dimensional task of moving a virtual object in a three dimensional space. These results indicate that to accomplish this task, subjects "usually break the task into a series of one or two-dimensional problems. They...move an object in the x-y plane before moving it into its final position by moving in the z direction. This dimensional decomposition ...[may] hold a clue as to how people think about multi-dimensional tasks" (p.3). Haptic feedback continues to be explored through virtual reality and the development of tactile displays for sensory communication and telerobotics applications. The information channel provided through tactile feedback can result in superior spatial orientation capabilities. If the visual stimulus is presented consistent with a haptic stimulus, the learning that results may be strengthened by combining modalities to form visual representations and mental images of stimuli.

Self-Correction of Learning Problems. The intention of the researcher is to provide strategies to the subjects which will be enabling, rather than imposing some form of external control over their learning ability. Instead of insisting that the subject adhere to the singular perspective of a target symbol, subjects are encouraged to invent and explore to gain access to and control of the VGM. As the subject gains confidence activating this internal mechanism to perform spatial orientation manipulations, success in identifying symbols and decoding them may assist the subject to develop self-correcting tendencies. The term self-correcting tendencies is defined as a three-step process of awareness, decisiveness, and reorientation. In step-one, the subject becomes self-aware that the perceived orientation is inconsistent with the target orientation. Step-two occurs when the feedback provided by the self-awareness that a mismatch has been made assists the subject to make the decision to perform a repositioning to create the desired match. Step-three occurs when the subject reorients the stimulus to create a match with the target symbol.

The development of self-correcting tendencies may provide the subjects with long-lasting metacognitive strategies. It is proposed that the process may become internalized and may be recalled in the abscence of the instructor, as compared to teacher-directed reading and thinking strategies which create a learner/teacher dependency, the usefulness of which may erode for the learner in the absence of the instructor.

The development of self-correcting tendencies is proposed to operate synchronistically with the access-consciousness of the human mind. According to Pinker (1997), access-consciousness refers to "what kinds of information the different parts of the mind make available to one another "(p.136). Access-consciousness operates to route information relevant to solving a problem, while irrelevant information is held back. Access-consciousness has four features; awareness of perceptual field (of sensation such as color, shape, sound, and smell), attention (information is rotated into and out of short-term memory), emotion (sensations and thoughts can be pleasant or unpleasant, interesting or repelling), and an executive I (which appears to make choices and act altering behavior). Pinker (1997) states "each of these features discards some information in the nervous system, defining the highways of access-consciousness. And each has a clear role in the adaptive organization of thought and perception to serve rational decision making and action" (p.139).

Awareness of the perceptual field in visual processing is intiated at a beginnig level with input of the visual stimuli from the rods and cones in the retina, through an intermediate level of processing representing the perception of egdes, depths, and surfaces, to a tertiary level of awareness where objects are recognized. Attention is paramount to conscious access. Pinker describes the spotlight of attention as a feature of consciousness-access:

> "It serves as the quintessential demonstration that unconscious parallel processing (in which many inputs are processed at the same time, each by its own mini-processor) can only go so far. An early stage of parallel processing does what it can, and passes along a representation from which a more cramped and plodding processor must select the information it needs" (p.140).

There is a point at which unconscious processing leaves off and conscious processing begins which divides visual information processing into an unconscious parallel stage and a conscious serial stage. This point is reached once parallel, unconscious processing has labelled locations in the visual field with a color, contour, depth, and motion. Then these combinations need to be consciously computed, at one location at a time. Pinker defines the spotlight of attention as "a programmable logic machine that looks at one part of the visual field at a time through a narrow, movable window, and passes on its answer to the rest of cognition" (p.141). The emotional coloring of an experience affects access-consciousness. Pleasurable experiences form representations which trigger positive goal states, which subsequently trigger information gathering, problem-solving, and behavior.

The executive I, represents the funneling of control to an executive process experienced as a sense of self or will. According to Pinker (1997) "the anterior cingulate sulcus, which receives input from many higher perceptual areas and is connected to higher levels of the motor system" (p.144), is located in the frontal lobes of the brain and is believed to house the decision-making circuitry of the brain. It is this executive function which is invoved in the processing of information that causes "the the eyes to point at one object at a time; they can't fixate on the empty space halfway between two interesting objects or wobble between them in a tug of war" (Pinker, 1998, p.144).

Statement of Hypotheses (Conceptual)

Encoding stimuli in a particular way will improve recall if encoding in that way increases the access to remember information. For example, encoding *three-dimensional representational objects* of letters and numerals holographically, while utilizing *haptic enhancer rehearsal* strategies may permit the subject to covertly manipulate the objects and may enable him/her to exercise control over the *VGM*. The gaining of control of the VGM may improve recall.

Scientific research supports the idea that indicators of *spatial orientation mechanisms* exist in lower order animals. According to Long(1991), animal navigation provides evidence that animal migration is under the control of sensory capabilities including for: a) birds- using the sun as a compass, stars patterns as night guides, olafactory markers, ultraviolet light, wind-generated low frequency sound, and magnetic field detection; b) honeybees- polarized light patterns; c) bats- sonar and echolocation; d) sharks- electrical field detection and geomagnetic gradient fields; e) ants- blue and ultraviolet polarized light patterns; f) bacteria- magnetic polarity orienting to earth's magnetic field; g) turtles- dark silhouette identification and wave motion detection; h) salmon- olafactory imprinting resulting in landscape imprinting; and, i) snakes- infrared sensing.

Long (1991) cites Griffin and Kreithen in their discussion on the difficulty of replicating migratory behavior under experimental conditions. Despite the abundant data obtained through this field of inquiry, these researchers believe that to fully explain animal migration a new sensory channel using a factor X needs to be discovered as existing theories do not completely explain behavior.

Pribram (1971) cites evidence for a cortical imagery mechanism in humans through the analysis of visual perception experiments. Studies have shown that the cerebral cortex may be tuned to different ranges of spatial information (Fergus & Campbell, 1968;1969). Spatial orientation or position in space, is a spatial dimension, which is more difficult to generalize than others such as magnification (Blakemore & Campbell, 1969), and size and shape constancy (Bower, 1966).

Sutherland (1968) states that the capacity to classify a shape as the same shape regardless of size, altered through changing distance or magnification is innately set. It has been found to be present in infants as early as six weeks of age (Bower, 1966). This innate process is attributed to the ability of infants to register *motion parallax* and *binocular parallax*. Pribram (1971) hypothesizes that this innate ability is made possible by a built-in mechanism capable of handling *parallax*- the holographic process which is constructed by a parallactic process called an *interference effect*.

Pribram (1971) and Blakemore & Campbell (1969) discuss findings on the effects of rotation on visually evoked responses. There is a limited range of spatial dimensions that the visual system can accomodate with speed making object identification easier when an object is viewed in the learned orientation.

Support for the three-dimensional holographic memory hypothesis is found in visual perception studies with infants. Pribram (1971) cites experiments, conducted by Bower (1966), which demonstrated that the retinal and neural mechanisms for *feature detection* are developed in humans at birth. This is contrary to the view previously held by Hebb and others that experience was necessary for receptor function to develop. The innate ability of infants to recognize (by size, shape and binocular vision) and match two-dimensional pictures substituted for three-dimensional objects at six weeks (Bower,1966) and the development of depth perception and binocular vision by four months (Nash, 1977) suggest that an inborn mechanism is in place at birth which allows infants to register visual information.

Pribram (1971) hypothesizes that the holographic process is the parallactic cortical mechanism responsible for the innate ability of visual perception in infants. The holographic process can accomodate the shift from two-to three-dimensional perspectives, the generalization for size, magnification and distance, and spatial orientation.

Support for the use of two-dimensional haptic enhancers and verbal scripting for short-term to long-term memory transmission during *interneurosensory learning* for basic computational facts is found in the studies conducted by Flaro (1989), on *cognitive ability patterning (CAP),* with elementary gifted and learning disabled students. CAP identifies the cognitive strategies and mental mechanisms of successful gifted students and teaching them to the learning disabled.

Flaro's work focussed upon teaching children without proficient internal visual processing systems. Flaro (1989) cites research conducted by Bandler & Grinder (1977) who developed the eye-movement hypothesis which implicates horizontal and vertical ocular movements as potential indices of cognitive processing. Flaro's (1989), procedure views eye movement and cerebral lateralization as techniques that register information in memory (see Figure 3). Flaro (1989) reports improved student performance on basic facts recall. This technique has been utilized successfully by this writer with her own students.

Neuroimaging techniques, utilizing sophisticated brainscanning technology, may provide a means of detecting the existence of a brain mechanism such as the hypothesized VGM. In theory, were such a biological mechanism to exist, then it's electrical gradient would be altered when it is activated a change that could be detected by brain sensing equipment.

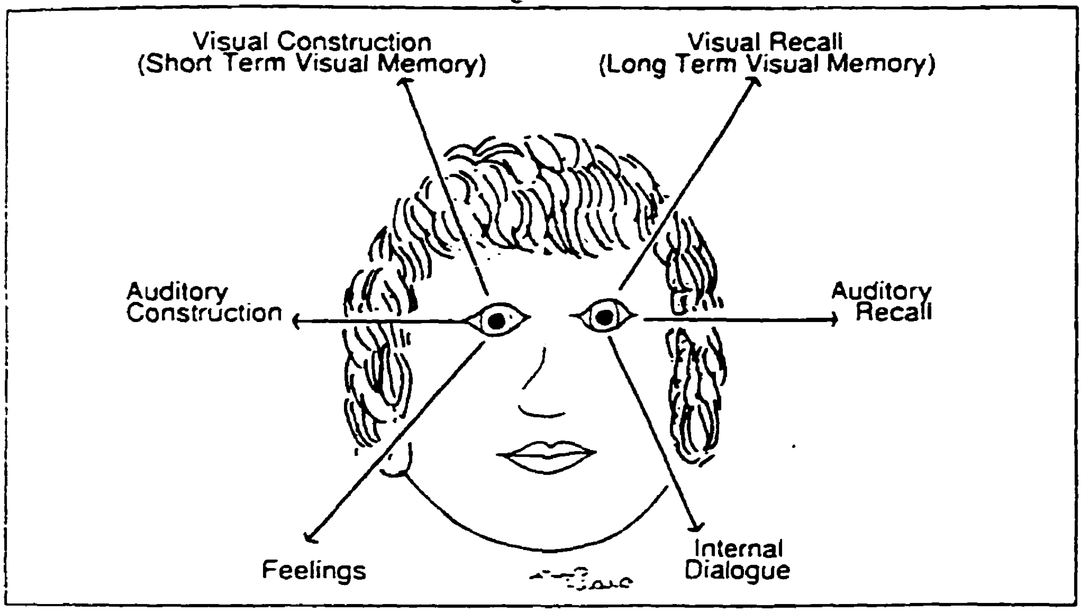


Figure 3. Flaro's interpretation of Bandler and Grinder's (1977) hypothesis that the direction horizontal, lateral, or vertical eye movement is reflective of underlying cognitive processes and hemispheric styles. These eye-movement patterns are generalizations of the internal processing and cognitive styles. Rsearch indicates that eye-movement patterns are a reliable measure for indexing internal processes. A right-handed student who moves his/her eyes up and to the left in response to a question or verbal instruction is accessing past images or pictorial representations associated with previously acquired knowledge. The student is remembering what Haber (1969) referred to as eidetic images. The student who looks up and to the right when responding is constructing pictures of ththings never seen before like a purple cow with dalmation spots. Upper-right quadrant eye movement activates the left cerebral (visual) sequential functional properties of the contralateral (opposite) hemisphere. Conjugate lateral eye movement indicates auditory processing. Lateral eye movements to the left activates past auditory memories such as song lyrics, poems and nonverbal sounds. Right-eye movement represents auditory construction, putting thoughts into words. Downward eye movement to the left is associated with inner dialogue and can be accompanied by mouth motions or subvocalizations. Downward to the right eye movement represents the kinesthetic processing of feelings. [From Flaro, 1989.]

Importance of the Study

The findings of this study have the potential to create pedagogical implications which may lead to the reform of the educational practices of early years educators. For example, it is the experience of the researcher to observe the overt correction by educators of reversals(e.g.b/d), inversions (e.g. u/n), and rotations (e.g.6/9,5/) in the teaching of reading to early years students. It is accepted that memory is an active process where stimulus information is retained by bringing knowledge of past events forward to organize, recode, and encode that information. How does a child who encounters a letter or numeral they've been repeatedly told they *do wrong*ly, integrate the stimulus information when past experience has taught them they don't know it? It is proposed that these perceived errors are not mistakes but merely different perspectives of the same visual stimulus, which have not yet been brought under the student's control by an internal spatial orientation device, the gyroscopic mechanism or VGM. The insistence that the student see a singular perspective may stifle his/her exploration of these representational forms. Further, overt correction may prevent the student from taking risks in decoding activities and may reduce the student's opportunity to integrate existing knowledge or new learning with previous knowledge. It is proposed that young learners be encouraged to explore and invent during the encoding and recoding processes. It is proposed that gaining access to the VGM is a natural process which occurs during a window of opportunity which coincides with the pre-logical years. There may be an over emphasis on drilling the phonological characteristics of letters and numerals in pedagogical practice with the expectation that the student will develop the ability to visually recall phonologically acquired information. Research shows that the ability to recall visually encoded stimuli does not depend upon the phonological features of the stimuli (Dillion & Reid, 1969; Posner & Rossman, 1965; Watkins, Watkins, Craik, & Muzuryk, 1973). To compensate for this apparent oversight, selected tasks utilizing haptic rehearsal enhancers are proposed as instructional tools for assisting pre-logical thinkers with the ability to encode, recode, and recall visual stimuli.

The results of this study may be of interest to researchers examining *dyslexia*, as gaining access to or control of the proposed VGM may lead to treatment or therapies for individuals experiencing the visual processing disabilities associated with dyslexia. Knowledge from this experiment may have some value for developing learning strategies for blind students because the treatment conditions utilize touch sensation to enhance visualization within the brain. Data may encourage future research with a replication study or by taking the research ideas into a virtual environment with hand and headset technology.

Scope and Delimitations of the Study

The results of this study may provide a basis for future inquiry for the holographic memory models and the VGM. Evidence may explain one of the brain's imaging systems by articulating the three-dimensional aspects of memory. Results will be limited to the subjects involved and not generalizeable to a larger population.

Outline of the Remainder of the Thesis

Following, are the literature review, methodology and results sections, references, and appendices. The literature review overviews memory and provides an historical background for memory research. A chronolgy of holographic brain theory presents the researchers and their postulated theories which contributed to its development. The methodology section provides an overview of the research method and design including; subject description, variables, hypotheses, null hypotheses, pilot study proposal, population description, ethical considerations, sample selection, instrumentation, field procedures, data collection, data processing and analysis (statistical), methodological assumptions, and limitations.

CHAPTER 2

Literature Review

Overview

Memory research is a massive field of inquiry that is best explored with an open attitude and an unwillingness to see through the eyes of any one theory or by adhering to the principles of any one theorist (Donahoe & Wessels, 1980). Historically, the role of memory in learning has focussed upon gaining an understanding of brain functions. In the 1990's, the pursuit brain theory research requires the integration and synthesis of the record of information from the behavioral to the genetic levels. Huerta (1998) states, " At each of these many and diverse levels there has been an explosion of information, with a concomitant specialization of scientists" (p.2). As a result our understanding of memory has become varied and increasingly complex. A cohesive perspective of brain theory research, in particular the study of visual memory, requires that the findings of psychologists, psychiatrists, neurologists, physiologists, and bio-molecular scientists be considered. These perspectives are presented and discussed in this chapter. Conceptual issues related to holographic models of memory are selected as a basis for the proposed VGM, operating phenomonologically within holographic memory.

The holographic memory model (HMM) developed concomitantly with the introduction of laser technology in 1964, which validated Dennis Gabor's theoretical model of the holograph (1946) for which he was awarded the Nobel Prize for Physics in 1970. This position oriented problem-solving approach to the presentation of the literature review is intended to: a) contribute to the scientific evolution of brain theory research by developing hypotheses for this study; b) lead to the development of methodological procedures to support the hypothesized VGM in pre-logical thinkers; and c) result in an experimental design to be applied within the context of the educational learning environment of early years subjects.

While molecular explanations of memory appear to be more sophisticated, to the theorist they are actually less complex because they can provide quantifiable, logical explanations for memory at a microscopic level. Technology reduces to simple biological terms a mystery that for over a hundred years has been widely studied from a macroscopic behavioral perspective (see Figure 4 Inverted Macro to Micro Cascades Model of Memory). The behaviorist perspective has proven to be less quantifiable. Despite the testing of assumptions, evidence fails to show support for the experimental hypotheses which have persisted to shape the way in which academics, psychologists, and educators shape the ways in which subjects are studied and taught.

Macro to Micro Inverted Cascade Models of Memory

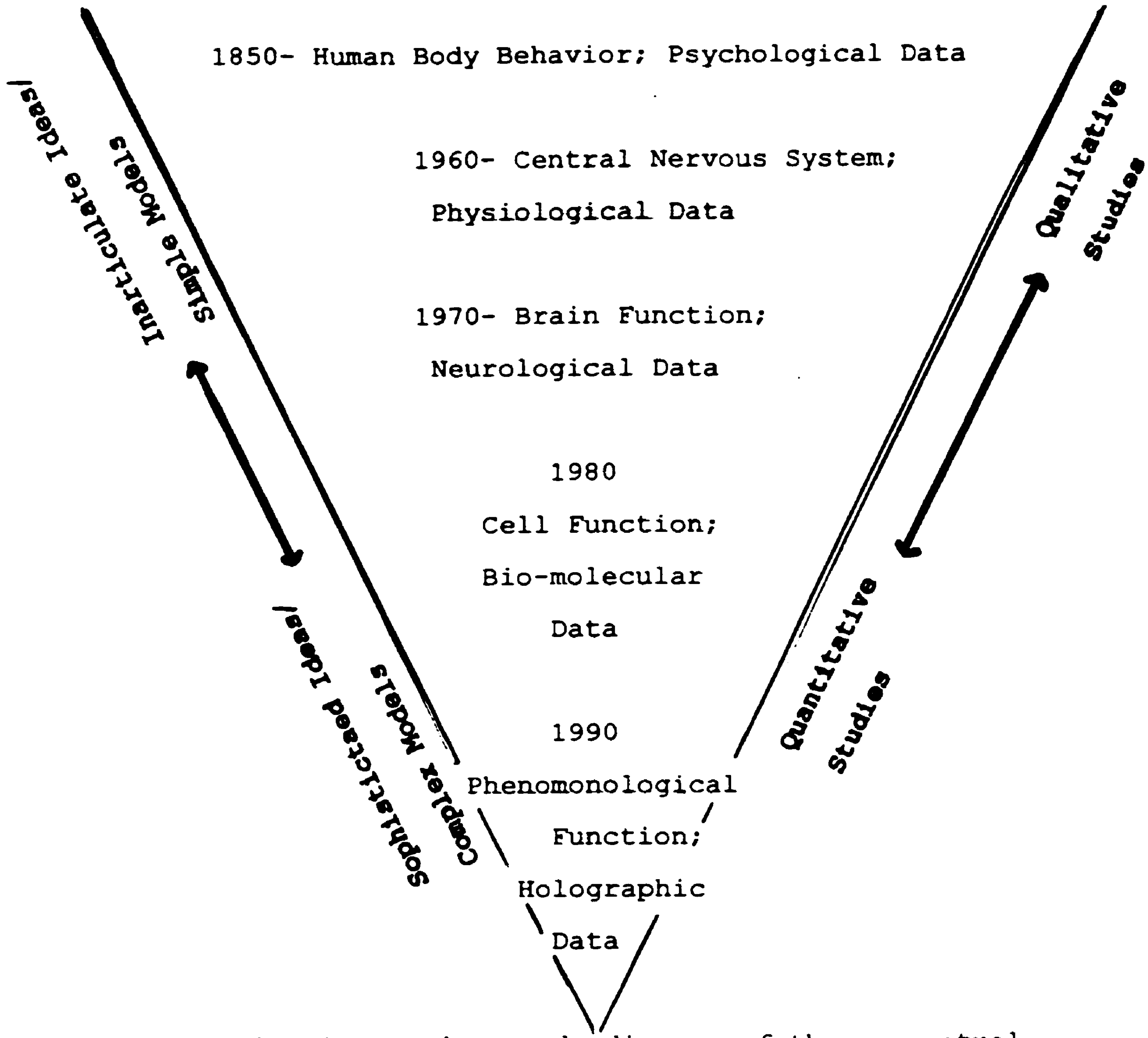


Figure 4. Inverted cascade diagram of the conceptual framework for Macro to Micro Models of Memory

Traditionally, learning and memory have been studied as though they were different phenomena (Donahoe & Wessels, 1980). Viewed this way within its own respective theory, learning is defined by Tarpy and Mayer (1978) as "an inferred change in the organism's mental state that results from experience and which influences in a relatively permanent fashion the organism's potential for subsequent adaptive behavior" (p. 3). The general model of memory when viewed as a distinct phenomena from the process of learning is that memory is a repository for acquired information. Four memory storage systems widely accepted during the 1960's include; short-term sensory store (STSS), short-term memory (STM), working intermediate memory (WM) and long-term memory (LTM)(see Figure 5). Defined by Tarpy and Mayer (1978):

> STSS has infinite capacity, represents visually presented information as an exact visual image, and loses information by having it decay very rapidly... STM is a limited capacity store, represents information as an auditory echo, and loses information by having it displaced by something else...LTM [has a] capacity [that] is technically infinite...information is represented in a meaningful, organized, abstract way, and information is lost because of interference or retrieval failure. (p.271)

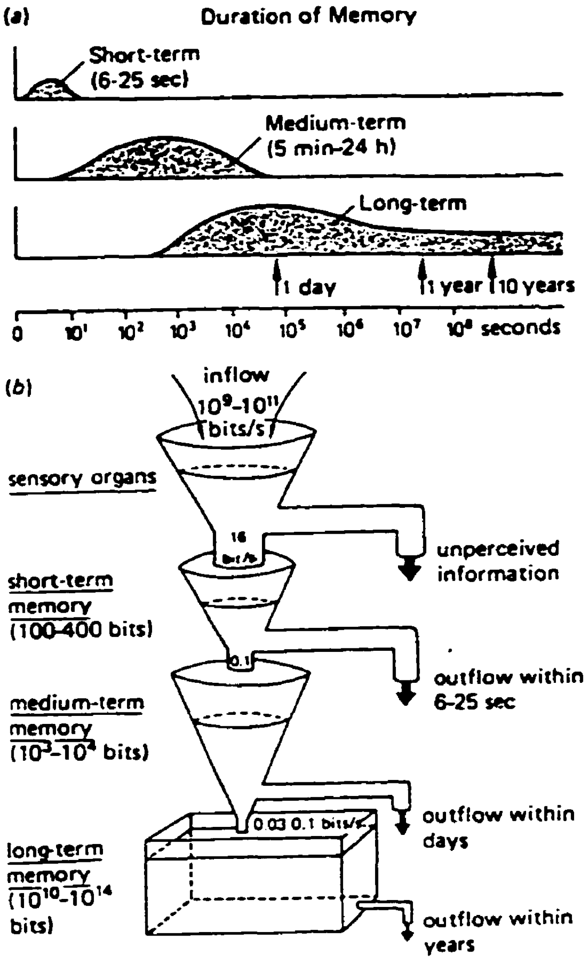


Figure 5. Rahmann and Rahmann's (1992) diagram of the stages in human memory: short-, medium-, and long-term. (a) Duration of memory in seconds. (b) Conceptualization of information inflow, outflow, and capacity. Human memory functions on three levels. Short-term memory is where all information arriving from sensory organs is stored for ca. 6 to 25 seconds. It includes our active consciousness which is gathered from sensory organs or that is reactivated from long-term storage in the sense of remembering. Approximately 10^9 to 10^{10} bits of information reach the nervous system each second. But only 16 bits per second can flow into consciousness or short-term memory storage with the residual information going unperceived. Short-term storage has a capacity of approximately 100 to 400 bits. Medium-term memory takes only a fraction (0.3 to 1 bit/sec) of the information from the short-term reservoir. Storage time ranges from several minutes to several hours. Storage capacity is thought to be ca at 10^3 to 10^4 bits (see Figure 4 b). It represents the unstable precursor stage to long-term memory, filtering from the continuous incoming information only that which is most essential to the recipient. Long-term memory, receives very few bits of information (0.03 to 0.1 bits/sec) per unit time. These bits are passed on from medium-term memory subsequent to selective control processes and are stored for days, months , or a lifetime. The capacity of long-term memory storage is thought to be 10^{10} to 10^{14} bits. [From Rahmann and Rahmann, 1992.]

Information moves from one memory store to the next through a series of control processes, attention, rehearsal and encoding. Attention regulates transfer from the sensory organs or STSS to STM, rehearsal in STM maintains the information keeping the information available for encoding and WM integrates them into LTM where it may be retained permanently.

Evidence emerging from the studies of the 1960's led to the information processing approach based on a human/machine analogy which is limited because humans are qualitatively different than machines and unlike computers are not soley processors of information. For the purpose of experimental analysis memory has been postulated into four sub-categories with three stages of information processing, encoding, storage and retrieval. While these distinctions are tentative, they have shaped the direction of scientific inquiry. As a result, the multistage storage distinction among the short-term sensory store (STSS), short-term memory (STM), long-term memory (LTM), and working memory (WM) as independent and interrelated entities has been widely criticized (Melton, 1963; Atkinson & Shiffrin, 1968; and, Craik & Lockhart, 1972). Learning and memory may be seated differentially along the same continuum. According to Tarpy and Mayer (1978) this framework:

> assumes that memory is a unitary continuum with differences in learning and memory due to differences in the type of rehearsal and coding processes used;

> this alternative shifts the focus from the distiction among memory stores to the controlling processes like attention, rehearsal, and encoding. (p. 293)

The domain of classical brain theory research includes associationism, behaviorism, Darwinism, Gestalt Psychology and cognitivism or the constructivist learning theories, none of which can wholly account for the following five phenomenas which have become of interest to this researcher. They are proposed as theoretical missing links in widely accepted learning theory. While merely speculative in nature, they are phenomenas which cannot be accounted for within the current field of classical brain theory research.

First, according to Csikszentmihalyi (1990) the human brain stores more information in a lifetime than is physiologically possible due to the rate at which data can be stored during neuronal electrical impulse transmission. Based upon Czikszentmihalyi's proposal that it takes 1/18th second to discriminate between seven bits of information, this researcher performed a calculation to determine the number of bits of information the human brain could be expected to store during a lifetime (see Appendix C). The result of this calculation, estimated on the basis of 16 waking hours per day during which input may be received and a lifepan of 70 years, is that the human brain may be expected to store approximately 185 billion bits of information. Oschman, J. and Oschman, N. (1995) cite John van Neuman's calculation on the vast capacity of memory.

"The Hungarian physicist and mathematician, John van Neumann, calculated that during an average lifetime some 280,000,000,000,000,000,000 or 10^{21} bits of information are stored in the brain" (p.7). The discrepancy between the two estimates confounds the anatomical, biophysical and electrophysical theories of information transmission because the accumulation of knowledge over a lifetime exceeds what can be transmitted electrically at the physiological level. Discounting the acceleration of the nerve impulse rate (akin to increasing the baud of a telephone modem) to accomodate an increase in the rate of data transmission, or by extending life beyond a conventional lifespan it seems reasonable that another means by which information is stored within the brain may exist, operating concurrently with nerve impulse transmission.

Second, the mental manipulation of letters to perform an abstract substitution was observed by the researcher in her daughter Jennifer McCall (1992), who at the age of five chronolgical years made the following declaration one day while driving along in the car:

> "Mommy, did you know that if you keep the M and the little c, and change the D for a C, and the O for an A, and leave out the N and the A, and keep the L, and change the D for an L, and add the apostrophe S, you'd have McCall's instead of McDonald's?"

This confounds cognitive Piagetian theory which proposes that developmentally children begin to acquire the ability to reason abstractly during the Concrete-Operational Stage: 7-11 years a time at which "the child develops the ability to perform mental operations" (Sund, 1976 p.11).

Third, once the ability to read is achieved, it is possible to read mirror images. In 1998 the researcher observed girls between seven and eleven chronological years of age reading the mirror image on Spice Girls washable tattoos. Children of this age are believed to perform concrete operations, with objects. To reverse a thought process (in this case manipulating the tattoo image) it is necessary for the child to manipulate it to modify it. The thought of changing the form of the tattoo must be preceeded by actually doing it physically. An example of the abstract right side up orientation in a young child is found in an observation of the researcher's three and a half year old nephew. He was seated with a Duplo catalogue which he had arranged perpendicular and upside down on a step to his right. When asked if he wanted to read it the right side up he responded by saying he could do it like this and proceeded to point out the familiar items in the catalogue indicating those he had and the ones he would like to have from the section for children zero to three years of age. He then turned to the section for children three to five years of age called Duplo Tools. He indicated that he didn't have any of these toys and became deeply engrossed in a kit in which he recognized a bulldozer and a helicopter. He then hesitated and questioned "Aunty Linda I wonder what this is?" (1998), indicating a third item he was unfamiliar with. When informed that the item in question was a rocket and rocket launcher Eliot stared at the picture for a moment, then he hopped off the step rotating his complete body a full 180 degrees, positioning his body directly infront of the picture which was now right side up. He appeared to intuitively reposition his body, to the necessary orientation to bring the picture into line with his initial upside down view of the items. These two examples confound Piagetian theory, as the transformation that must be performed to read a mirror or upside down image of a pictorially concrete stimulus requires the propositional thinking associated with the Formal-Operation Stage: 11-14 years.

Fourth, the instantaneous recall and spontaneous recovery of stored information from human memory which according to Sandberg (1997) can occur in a few hundred milliseconds is a phenomena which cannot be accounted for by a biomolecular perspective. The search for the memory engram or memory trace has been aggressively pursued in the literature of the twentieth century. According to Oschmann and Oschmann (1995);

> "The most significant lines of inquiry arose from studies of neurophysiologists who continued Penfield's research for the location of the [memory] engram [in

> the 1920s]...Harvard psychologist Karl Lashley's body of research spanning thirty years, resulted in an unsuccessful search for the engram" (p.3).

The search for the memory engram continued from the 1950s, influenced by the biomolecular pursuit of a single memory molecule that could not be found which lead to the current investigation of DNA-RNA-protein complexes. Yuzaki (1998) is investigating the modification of mammalian gene expression by examining the effects of two neurotransmitters on the new synapse formation associated with the long-lasting memory that requires new RNA/DNA protein synthesis. Nicholoson (1997) summarizes the research in process conducted by Cavallaro, Meiri, Musco, Goldberg, and Alkon who are attempting to identify the proteins responsible for associative memory using RNA fingerprinting to identify candidate memory-related genes in the hippocampus, a region of the mammalian brain involved in spatial learning. Their preliminary results find that successive RNA screening illustrates a spectrum of memory-related genes in the hippocampus. According to Oschmann & Oschmann, 1995;

> "The brain's monopoly on memory has been eroding for many decades. Studies done as early as the 1940s demonstrated that certain simple reflexes can be conditioned or learned by spinal cord neurons that have been surgically disconnected from the brain [leading] to the conclusion that memory may be found in all parts of the nervous system" (pp.2-3).

Karl Pribram, continued the search for the engram with the view that memory is distributed throughout the brain and not localized in specific sites. A theory of memory that was consistent with this evidence needed to be developed. The time was right for a paradigm shift in the conceptualization of brain function. According to Oschmann and Oschmann (1995) in 1964, Leith and Upatnieks introduced modern holography, proving the holography theory postulated by Dennis Gabor in 1946. "Pribram...recognized that holography provided a single conceptual framework that could account for many of the remarkable aspects of memory... Pribram's subsequent work is responsible for the wide-spread application of the holographic model to brain function" (p.6).

Fifth, some students can read upside down and backwards with ease or horizontally, vertically and at 45 degree angles (Roberts, 1998) while others are unable to overcome the spatial disorientation of reversals, inversions, transpositions, and substitutions to decode the printed form. While the former can be accounted for within Gestalt theory reflecting the Gestalt principle of similarity, the latter confounds the same Gestalt principle which specifies that a visual stimulus will be oriented toward a Cartesian axis when forming visual perception.

The virtual gyrostatic mechanism (VGM) proposed, examines these five phenomenas and attempts to explain how learners can gain control of their spatial orientation abilities to develop self-righting tendencies. This view of memory cannot be nested soley within the classical brain theories because these theories alone cannot explain it. The models of holographic brain function provide a theoretical framework within which a phenomenological VGM may exist. These include the holographic memory models proposed by Prideaux (1998), Gabor (1949, 1961, 1969, 1991), Longuet-Higgins (1968), van Heerden (1970), Pribram (1969, 1971, 1985, 1986, 1991, 1993), Griffith (1968, 1973) and Cavanaugh (1975). These holographic models attempt to explain the ability of the brain to store an infinite capacity of information, the redundancy principle of the brain to store and use localized information that is not stored in a site specific repository, the retention of memory despite removal of portions of the cerebral cortex and during dream states, storage and retrieval of information that is not semantically encoded, how the function of an injured site of the brain may be assumed by another part of the brain, in particular when that damage occurs during early years development, the intuitive properties of acquired knowledge without prior physical experience, and of most importance to this study the existence of a three-dimensional perspective of visual information during encoding and retrieval.

Fundamental differences exist between the classical brain theories and the concommittant conventional anatomical, electrophysical, and psychophysical approaches to brain function, and, the HMM. For example, in holographic memory the processes of input storage and retrieval may be spectral transformations, rather than the generation of an action potential by electrical impulse transmission. This transformation occurs in a holographic domain located within the visual system (see Figure 6) where the main computational event of neurons is the polarization (input) and depolarization (retreival) at the dendritic membranes which resembles a Fourier-like transform. More specifically, in holographic memory input is stored in the brain in the holographic domain (three-dimensionally in a non-localized fashion). Each part of the hologram contains information of the whole as its features are distributed, not localized. Prideaux (1998) states:

> "the dendritic processes function to take time and spectral transformation of the episodes of perception. This transformed spectral transformation is stored distributed over large numbers of neurons. When the episode is remembered, an inverse transformation occurs that is also a result of dendritic processes" (p. 2).

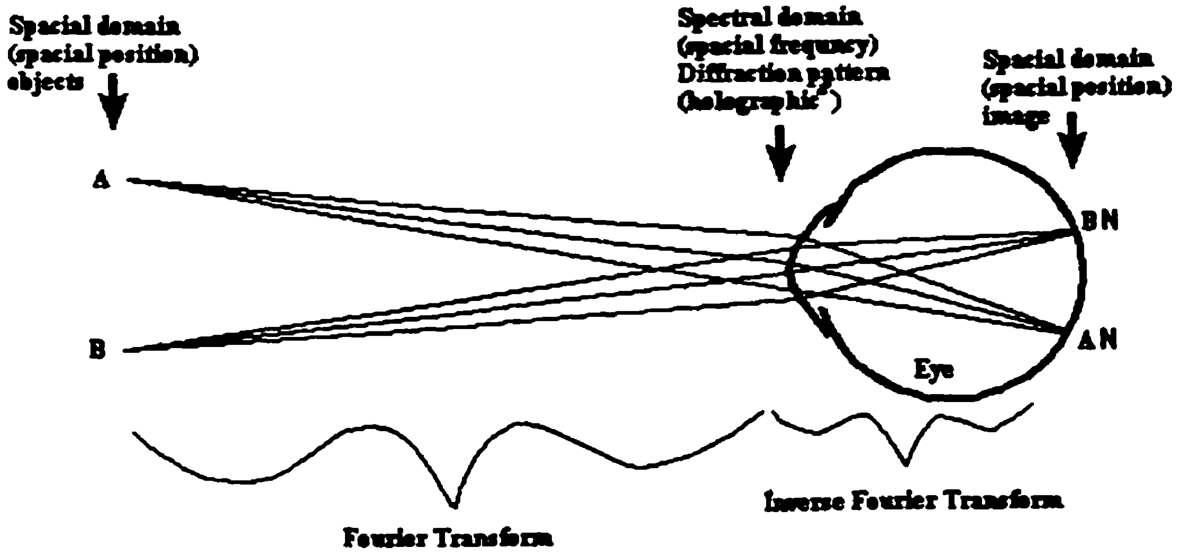


Figure 6. Prideaux's (1998) Diagram Expressing the Holographic Nature of Light Incident on the Surface of the Lens of the Eye. The holographic nature of light incident on the lens is illustrated, showing the light reflected from the spatial domain, or the spatial position of the stimulus object, undergoing a Fourier transform as it is received by the lens converting the information to a spectral domain with a spatial frequency generating the holographic diffraction pattern which then focuses upon the retina through an inverse Fourier transform resulting in a spatial image of the stimulus object. [From Prideaux, 1995.]

Evidence emerging from the studies of the 1960's led to the information processing approach based on a human/machine analogy which is limited by the qualitative differences between mankind and machines. For example humans are not soley processors of information. To analyze experimental data memory was postulated into four sub-categories with three stages of information processing, encoding, storage and retrieval. Input is first received by the sensory organs or STSS, rehearsal occurs the STM to maintain the information by making it available to the WM where it is encoded and integrated into LTM (see Figure 7). While these distinctions are tentative, their postulation has influenced the direction of subsequent scientific inquiry.

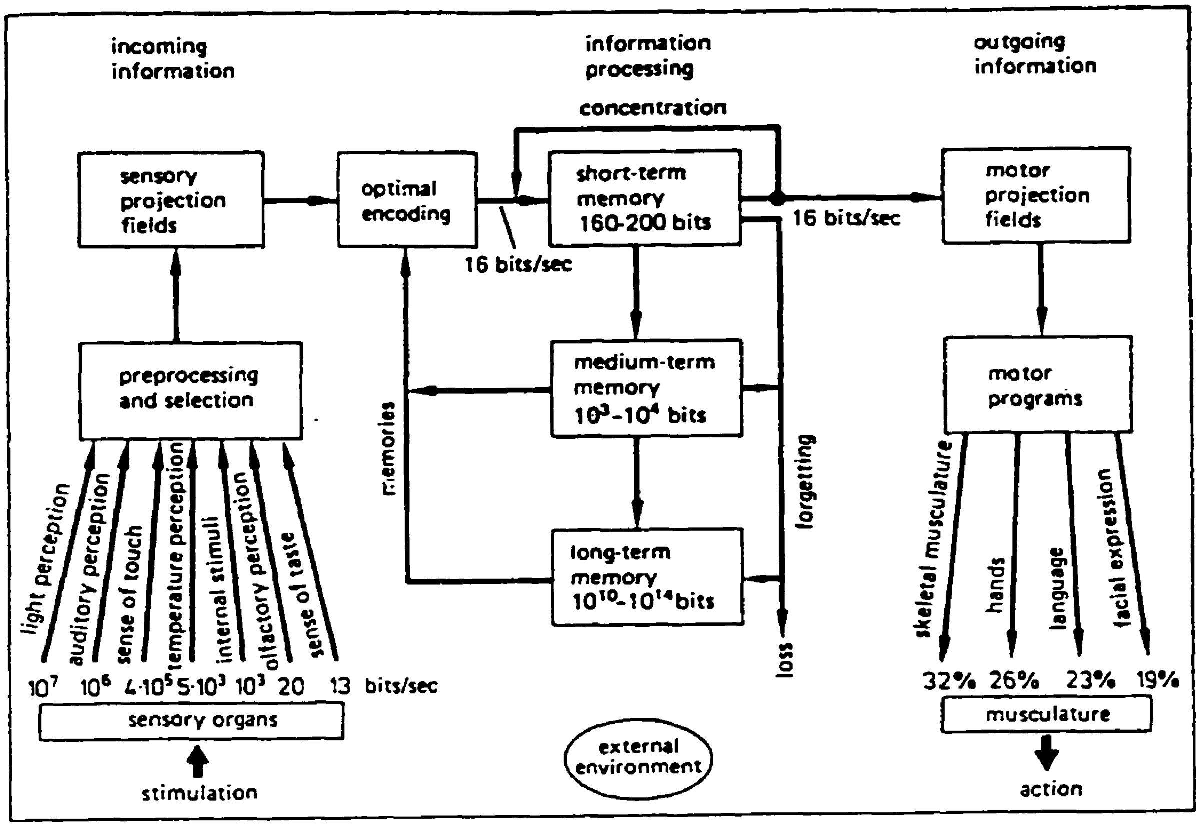


Figure 7. Rahmann and Rahmann's (1998) reprinting of Frank's (1969) diagram of the information flow underlying consciousness in humans. The factors which pertain to the flow of information responsible for regulating human consciousness are presented in Frank's overview. Human memory functions on three levels which include short-term memory, medium-term memory and long-term memory. Short-term memory includes our active consciousness which is comprised of information that the nervous system obtains directly through the sensory organs or that is reactive from long-term storage. Information arriving from the sensory organs is stored for ca. 6 to 25 seconds. Approximately 10^{9} to 10^{11} bits of information reach the nervous system every second from all the sensory organs, however only 16 bits per second can flow into one's consciousness, or short-term storage. Consequently the storage capacity of short-term memory is 100 to 400 bits. Medium-term memory takes a fraction, 0.3 to 1 bit/sec of the information from the short-term reservoir. Medium-term storage capacity is ca. 10^{3} to 10^{4} bits. It's storage time ranges from several minutes to several hours. It represents the unstable precursor stage to long-term memory. Long-term memory receives only 0.03 to 0.1 bits/sec. These are passed on from medium-term memory subsequent to the selective control processes and are stored from days to a lifetime. The capacity of long-term memory is thought to be 10^{10} to 10^{14} bits. [From Rahmann and Rahmann, 1998.)

As a result, the multi-stage storage distinction among the short-term sensory store (STSS), short-term memory (STM), long-term memory (LTM), and working memory (WM) as independent and interrelated entities has been widely criticized (Melton, 1962; Atkinson & Shiffrin, 1968; and, Craik and Lockart, 1972). Learning and memory may be seated differentially along the same continuum. According to Tarpy and Mayer (1978) this framework:

> assumes that memory is a unitary continuum with differences in learning and memory due to differences in the type of rehearsal and coding processes used; this alternative shifts the focus from the distinction among memory stores to the controlling processes like attention, rehearsal, and encoding. (p. 293)

Topic Selection

A comprehensive explanation of holographic memory theory and models of holographic memory is provided in the Models of Holographic Brain Function discussion which follows as part of this presentation of the background to the problem. To understand the ways in which the models of holographic brain function may be derived from or operate in distinction to the more widely accepted models prevalent in the field, an overview of classicical brain theories, the conventional anatomical, electrophysical, and psychophysical approaches to brain function is discussed next, to create a basis from which the VGM and holographic concepts introduced can be compared, and analyzed.

Historical Background

Historically, learning and memory are defined as distinctly different from one another. For example the study of learning focuses on the processes involved in acquisition and extinction while the study of memory focuses on the factors that affect acquisition and retention. While this traditional distinction is convenient for the purpose of research, it appears stronger in tradition than in its substance (Donahoe & Wessels, 1980). The construct that the two are mutually exclusive may be erroneous because memory is implicit in all learning, and learning and memory may be different aspects of the same phenomena.

Early experiments on memory were based upon associationistic theories, the predecessors of information-processing theories, where simple memory phenomena were analyzed in terms of their formations and associaitons. Researchers attempted to eliminate the effects of prior experience by manipulating experimental procedures (using nonsense information stimuli) and avoided complex memory phenomena. Critcism of these early theories resulted in the formulation of information-processing theories in the 1960s that adopted the strategy of studying complex memory phenomena and the development of computer technology. Information processing theories fail to adequately address the effects of prior experience in short-term memory on encoding and retrieval processes. For the purpose of experimental analysis, the field of memory has been postulated into three subcategories, sensory memory, short-term memory, and, long-term memory, with three stages of information processing, encoding, storage, and retrieval. While these distinctions are tentative, they have shaped the direction of scientific inquiry to date.

Classical brain theories: Associationistic Theory. This contemporary model originates with the philosophies of Aristotle, the early research of Hermann Ebbinghaus and the British associationists John Locke, David Hume, and George Berkley (Donahoe & Wessels, 1980). Within associationist theories, memory utilizes the activation of existing associations and forgetting occurs as a result of unlearning or blocking the association with competing associations. The basic tenet of associationism is that images and language can be analyzed in terms of the associations that are formed through experience. Associationists seek to discover the fundamental laws of memory by studying these associations under simple and well controlled conditions in which the effects of prior experience does not intrude. British associationist Johne Locke (1632- 1704), who challenged Descarte's theory that ideas are innate by proposing that the content of the mind is derived from experience and adamantly supporting the notion of the mind as tabula rasa (blank slate), and David Hartley (1705-1757) proposed laws of learning that reflect a cohesion among contiguous (ocurring close together) sensations and ideas. Hermann Ebbinghaus (1850-1909) found support for Hartley's ideas, in particular that forward associations are stronger than backward ones and that repetition of stimulii strengthens the corresponding association. He brought contiguity or association theory into a central position in studies on modern learning and memory theory. Associatonist theory has contributed valuable findings to the study of memory, including the emphasis on thorough experimentation and the interference theory of forgetting. Unfortunately, the effects of prior experience were found to intrude into the experiments despite controls such as using nonsense syllables in paired-associate learning procedures. The inability of the associationists to empirically quantify their hypothesis led to the subsequent cognitive learning theories which have dominated the field of memory research during the latter half of the twentieth century. The theory that the complexities of language can be analyzed adequately through the study of experience alone was challenged by Chomsky (1957), who introduced biological factors and transformational grammar as a more suitable analysis of language ability. During the 1950's and early 1960's, computer technology was introduced and a machine model of memory became advantageous to theorists (Donahoe & Wessels, 1980). The computer simulation models of memory and learning contributed to the demise of associationist theory. As a result, associationistic memory theory was found inadequate to provide a complete understanding of language and memory.

<u>Behavioral theory</u>. Behaviorist tradition devoted entirely to overt behavior popularized by John Watson (1878-1958) and B.F. Skinner (1963 -) proved to be restrictive because its precept that all behavior can be explained systematically and objectively was too inflexible to be accepted by the psychological community. The research methodology of the behaviorism theory, which was opposed to explaining behavior through conscious or mental experience and sought to reduce learning to a series of muscle contractions, developed quantifiable data under strict experimental controls that have shaped the way in which psychological investigation continues to be conducted today. Charles Darwin's (1809-1882) theory of evolution had two important implications for the study of learning. Firstly, his view of survival depended upon immediate adaptation to the environment by learning effectively from experiences. The survival of a species depended upon its ability to accomodate to change. Biologists examined this phenomena through the study of genetics, while psychologists sought to explain adaptation through the study of learning. The second implication for human learning was that, because man was believed to have evolved from lower species of life, a continuity between species was implied. Therfore, if principles of genetics based on the study of lower animals could be applied to humans, then the principles of learning discovered through animal science might also be applicable to humans.

Gestalt theory. Gestalt psychology influenced learning research in the domains of perception and cognition. This field of inquiry was begun in Germany by Wertheimer, Kiffka, and Kohler and was brought by them to the United States in the 1930's. Wertheimer focussed his studies on the perception of movement which led to the phi phenomenon commonly associated with the motion perceived in moving pictures. The apparent movement was not dismissed as a perceptual illusion, but was perceived as a real experience which could not be explained by physical principles. Out of this discovery evolved the Gestalt approach to psychology which views an experience as something greater than the sum of its elements. Within this view, psychological experience can not be explained from the synthesis of its component parts. Ideas explaining the Gestaltqualitat or wholeness of experience insist that cognitive forces in the brain, not external sensory elements, influence perceptions, learning, and memory. The information processing during learning and memory are dynamic and become altered by the cognitive forces that created them.

Cognitive theory. Bartlett (1932), an early cognitivist, influenced by Gestalt psychology, examined memory as a reconstruction of past learning subject to the attitudes and cognitions of the individual. He found that subjects, when unable to retell facts from unfamiliar stories, substituted distorted recalls modified to reflect story details more in keeping with the subjects' cultural experiences. Bartlett (1932) concluded, "Remembering is not the re-excitation of innumerable fixed, lifeless and fragmentary traces. It is an imaginative reconstruction, or construction, built out of our attitude towards a whole active mass of organized past reactions or experience" (p. 213). This view was unpopular until the 1960's when learning and memory were brought into a new perspective by the constructivist models of learning.

Cognitive/constructivist theory. Information processing theory was introduced in the 1950's and developed extensively through the 1970's. Using machines to physically embody a theory about learning and memory permits the theorist to design and construct a mechanism which can simulate certain behaviors. Programming machines to behave in predictable ways , demonstrates the internal consistency of the behavior theory (Donahoe & Wessles, 1980). Computer-based theory of memory, introduced a new research strategy analyzing the complex phenomena on a molecular level rather than the previous macro levels which attempted to isolate mechanisms of memory in their constituent parts. Cognitive psychologists perceive memory as a processing system that, analogous to the computer, actively encodes, stores and retrieves information. The computer analogy is popularly used when analyzing the brain, and the visual system, in terms of neurophysiology (hardware) which include the component physical structures such as the retina and the visual cortex, or its information processing mechanisms (software) which include the operations carried out such as pattern recognition and storage in memory (Spoehr & Lehmkuhle, 1982).

Conventional anatomical, electrophysical and psychophysical approaches have dominated the field of inquiry into visual information processing. These approaches are discussed to provide a working knowledge of the historical development of brain theory research as it pertains to visual memory. The aspects of visual memory which cannot be explained within each of the approaches are explained and a new model is proposed and takes the form of the VGM.

Conventional anatomical, electrophysical, and psychophysical approaches to brain theory. In conventional theory the brain consists of distinct communication modules (regions of the brain) in which input is processed or stored (see Figure 8). With vision, specific features of the stimulus are stored in dedicated cortical cells which have parallel pathways to other modules to create the visual experience. This theory is analagous to the computer signal processing on an image where dedicated circuitry for edge detection interfaces with circuitry for color. These indivudual features of the image are processed in different dedicated circuits which are then linked through parallel pathways to other brain modules and combined to form perception. Conventional theory views the generation of the action potential as the main computational event in neurons.

Figure 8. **Brierley's brain diagrams (From Brierly, 1994).**

The Brain

Side view of the human brain. Adapted from UNESCO *Courier* January 1976.
Dotted area = bulb or lower brain stem. Hatched area = 'old' brain or upper brain stem.

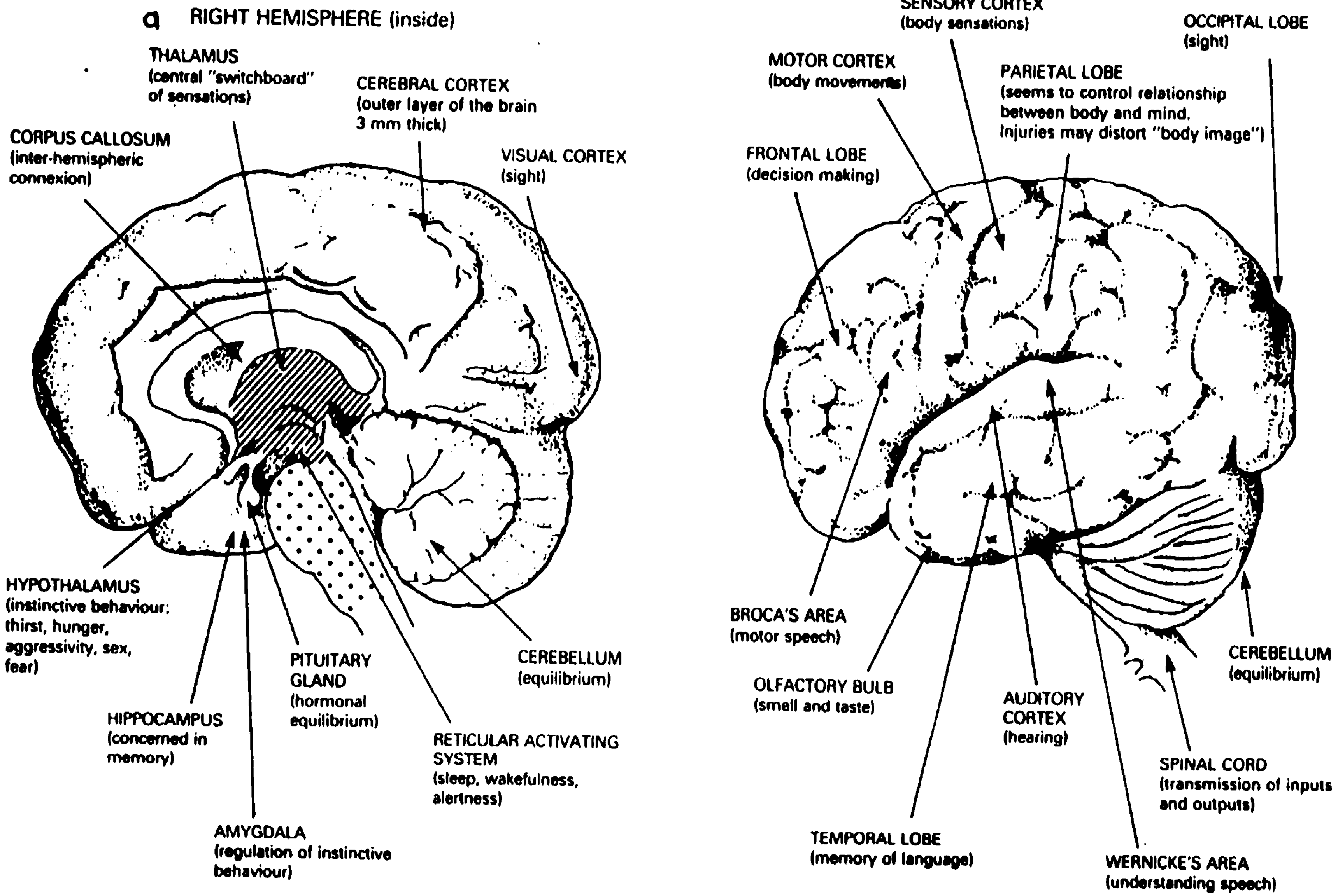


Figure 8. Brierley's human brain diagrams of (a) inside right hemisphere, and (b) outside left hemisphere. The adult brain weighs approximately1350 grammes and is estimated to contain 100 000 million cells. It consumes oxygen at a rate of 46 cubic cm per hour and converts glucose at a rate of 108 grammes per day. The breakdown of glucose by oxygen yields energy, approximately twenty watts per unit time or the amount of electricity required to illuminate a 20W bulb. The human brain is a single organ consisting of four interrelated parts; the cerebral cortex, the brain stem, the lower brain stem, and, the cerebellum. The cortex is the outer surface of the brain(grey and white matter) which is responsible for learning, thinking, and planning. The brain stem is located within the cortex in the middle of the skull underneath the pulpy white matter(of the cortex) and is considered the central core of the brain.. The brain stem includes interlinked structures, the thalamus, hypothalamus, pituitary gland and the reticular formation of complex nerve fibers responsible for attention, sleep, wakefulness and ultimately consciousness. The lower brain stem follows the spinal cord into the skull and controls breathing and temperature regulation. The cerebellum is second in size to the cortex and is situated at the back and below it. Deep corrugated side to side ridges increase its surface area. Referred to as the automatic pilot of the brain, the cerebellum acts upon conscious thoughts and coordinates the muscles to perform the movement functions, walking, reaching, grasping, and fine motor skills. When the cerebellum can not perform these precision oriented actions, the cortex compensates but the results obtained are delayed, exhaustive and imprecise.

The cortex is an immensely folded mantle of approximately 2000 cm. square. The cortex is approximately 3mm in depth and is formed from approximately 10 000 million nerve cells (neurones). Beneath the grey matter of the cortex lies the white matter formed from the axions or criss-crossing fibers of the neurones which conduct nerve impulses. These glial cells comprise 80 percent of the brain's mass and are believed to be important to memory. The cortex contains two halves connected by a band of nerves, the corpus calosum which enables the two hemispheres to work together, but how the mental unity and transmission of information occurs is unknown. The right (a) and left (b) hemispheres have different domains of specialization. The speech and movement functions are dominant functions of the left while visuospatial skills such as recognizing objects and reading are dominant functions of the right. However these domains of specialization are not mutually exclusive as subordinate ability has been found to develop in both hemispheres with compensatory abilities emerging when one side of the brain has been removed or damaged. Each hemisphere is divided into four lobes; temporal, occipital, parietal and frontal. The temporal lobe or hippocampus contains specific parts, hippocampi which are crucial in learning and memory. The left temporal lobe is involved in verbal coding and the learning and retention of words and letters. The right temporal lobe is involved in the recognition of verbal and auditory patterns with certain sites responsible for the final summation and storage of simple feature analysis. The occipital lobe on the back of the cotex is the primary visual area. The large side parts are the pareital lobes are beleived to specialize in the processing and storage of modality specific information such as vision, hearing, taste, smell and movement. This region may account for spatial orientation, the ability to find one's way home, dressing and in association with other parts of the cortex preserve a sense of bodily awareness. The large frontal area of the cortex is believed to be the association area. The nature of these enlarged lobes is believed to be heterogeneous with a variety of specialization function including; capacity to cooperate, restraint of aggressive and sexual behaviour, and, judging consequences of behavior.

The cortex has been mapped by recording the electrical impulses of the nerves that bring signals from the sense organs. Motor, touch, vision and hearing have been well charted while taste and smell have yet to be explored. The motor area of the cortex maps the muscles on the opposite side of the body. Approximately one half of the area is dedicated to the hands and speech organs. It takes 6 times more grey matter to move the lips than to move the entire trunk. Located behind the motor cortex, the sensory cortex represents the touch map of the entire body surface from the sense organs of the skin, again with an overrepresentation of the face and hands. The primary visual cortex located at the back of the brain receives input from the eyes in the form of simplified electrical and chemical codes. The functioning visual cortex uses a greater amount of oxygen than other parts of the brain when active. The visual cortex cells are believed to have generalizing properties, rather than specific ones where a particular column of cells will dertect a particular shape. Intact copies of objects or precise respresentations of scenes are not believed to be sent to the brain. However the way in which the brain classifies and combines the electrical and chemical signals into integrated forms is unknown. Other areas of the cortex are linked with the visual cortex and are believed to be responsible for interpreting the visual aspects of color, orientation, depth, motion, and texture. Current neurophysiological research has advanced the understanding of the function of the visual cortex, but how the visual patterns encoded in the brain are analyzed and interpreted to produce fully intgrated images is still unknown.

The brain stem contains the thalamus which acts as a conduit for the sensory input enroute to the cerebral cortex. Evidence suggests that the thalamus is associated with emotional drive and may alter signals from the sensory organs producing maps for vision, hearing and touch. The hypothalamus is located beneath the thalamus, on the floor of the skull, and regulates the organs of the autonomic or involuntary nervous system, and the pituitary gland which produces hormones. The pituitary gland lies below the hypothalamus and is responsible for growth and reproduction processes.

The lower brain stem, referred to as the bulb is responsible for functions that maintain life. The nerve cells of the spinal cord and bulb include synapses which transmit impulses on inborn pathways which remain electrophysically active even during sleep.

The cerebellum has been referred to analagously as a computer which programmed by the cerebral cortex executes the plans for skillful, complex movements requiring coordination, balance, equilibrium and locomotion. [From Brierly, 1994.]

This Euclidean-based geometric model of neuron transmission regards the firing of the action potential for a single cell or a network of cells as the trigger for memory or perception. Prideaux (1998) summarizes the principles of neural science proposed by Kendel, Schwartz and Jessell (1991). The information flow for visual perception is as follows. The retinal cells respond to small circular stimuli, the lateral geniculate nucleus cells respond to input, the primary visual cortex transforms the concentric receptive fields in at least three ways: a) the visual field is decomposed into short line segments of different orientation, through orientation column to form early discrimination of form and movements; b) input about color is processed through blobs which lack orientation selectivity; and c) input from the two eyes is combined through the ocular dominance columns, a step required for depth perception. Connections in the visual system are specific. Certain parts of the retina project to the lateral geniculate in the thalamus so that a complete visual field for each eye is represented in the nucleus (see Figure 9).

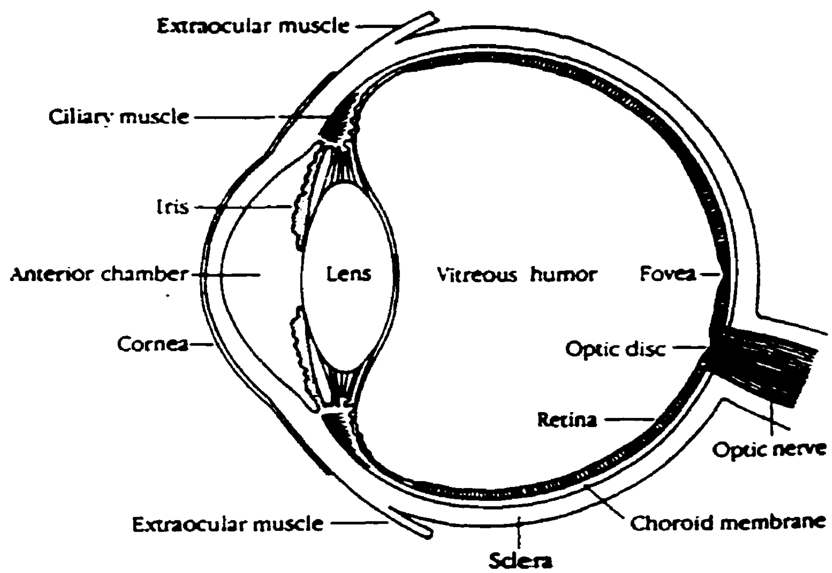


Figure .9. Spoehr and Lehmkuhle's schematic representation of the eye. The visible parts of the eye are the white of the eye or sclera, the coloured part of the eye or iris and the dark center of the iris, or pupil. External parts of the eye not readily seen include the six muscles which are attached to the exterior globe of the eye and cause the eye to move up and down and to rotate in its socket, and, the cornea which is a transparent covering on the front of the eye which refracts light rays focussing them upon the back of the eye. Internal parts of the eye include; the anterior chamber, or the cavity behind the cornea which contains the aqueous humor (a clear fluid absorbed as nutrition by the cornea). The iris is located behind the aqueous humor and infront of the lens. It is a circular muscle which contracts and relaxes to control the amount of light entering the eyes. The lens is transparent and transmits and focusses light upon the retina. It can change shape to keep a fixated stimulus in focus in a process called accommodation. The vitreous humor is a clear, jellylike fluid which fills the interior of the eye to produce its globe shape. The retina is attached to the back of the eye and performs the conversion of light energy to electrochemical energy. There are three distinctive features of the retina; the blood vessels that provide nutrients to the retinal cells, the fovea, a shallow depression void of neural tissue containing photoreceptors and the most sensitive area of the retina for resolving detail, and, the optic disc, the exit point of all the retinal nerve fibers. The optic disc does not contain photoreceptors and is called the blind spot because we can not see through this hole in our visual field. The retina contains two types of photoreceptor cells, rods and cones. Rods are concentrated outside the fovea and are most useful for night vision and low luminance levels because they contain photopigment which is most efficient at converting light energy to electrochemical nerve impulses. Cones are concentrated in and near the fovea and the photopigment of the cones varies to absorbe different wavelengths of light. Light must penetrate the neural tissue infront of the photoreceptors, including the ganglion cells in order for light to strike the photoreceptors. The signals from the photoreceptors are interpreted by the retinal cells with that output being trasnmitted to the ganglion cells of the retina which depart the eye through the optic nerve at the optic disc. There are three types of ganglion cells, X-, Y-, and W-cells(not shown). Y-cells are located in the periphery of the retina and have large cell bodies and thick axons conducting electrical nerve impulses quickly. X-cells are concentrate in and around the fovea and have smaller cell bodies and axons that conduct electrical nerve impulses at a slower rate than the Y-cells. The W-cells are predominantly outside the fovea have very small cell bodies and axons which conduct electrical nerve impulses at a very slow rate. The axons of the ganglion cells leave the eye through the optic nerve. The axons that originate from nasal halves of the two retinas (the half of the retina closer to the nose) cross at the optic chiasm and travel to the opposite side of the brain while the axons of the ganglion cells in the temporal halves of both retinas (the halves closer to the temple) do not cross at the optic chiasm, staying on the same side of the brain. In this way all the axons of cells that are responsible for the same part of the visual field are routed to the same hemisphere. The information is carried to the visual cortex along two pathways, geniculo-striate or tectocortical. [From Spoehr and Lehmkuhle 1982.]

Retinal cells target specific areas of the brain stem. Each geniculate axon terminates in the visual cortex, primarily in layer 4. The cells of the visual cortex are arranged into orientation specific columns, ocular dominance columns, and blobs. Horizontal connections between some of these neurons permits the flow of information between columns which seem to function like elementary computational models . Information travels vertically through layers and horizontally between columns with each cell group acting as dedicated circuits which process an transmitting input (see Figure 10).

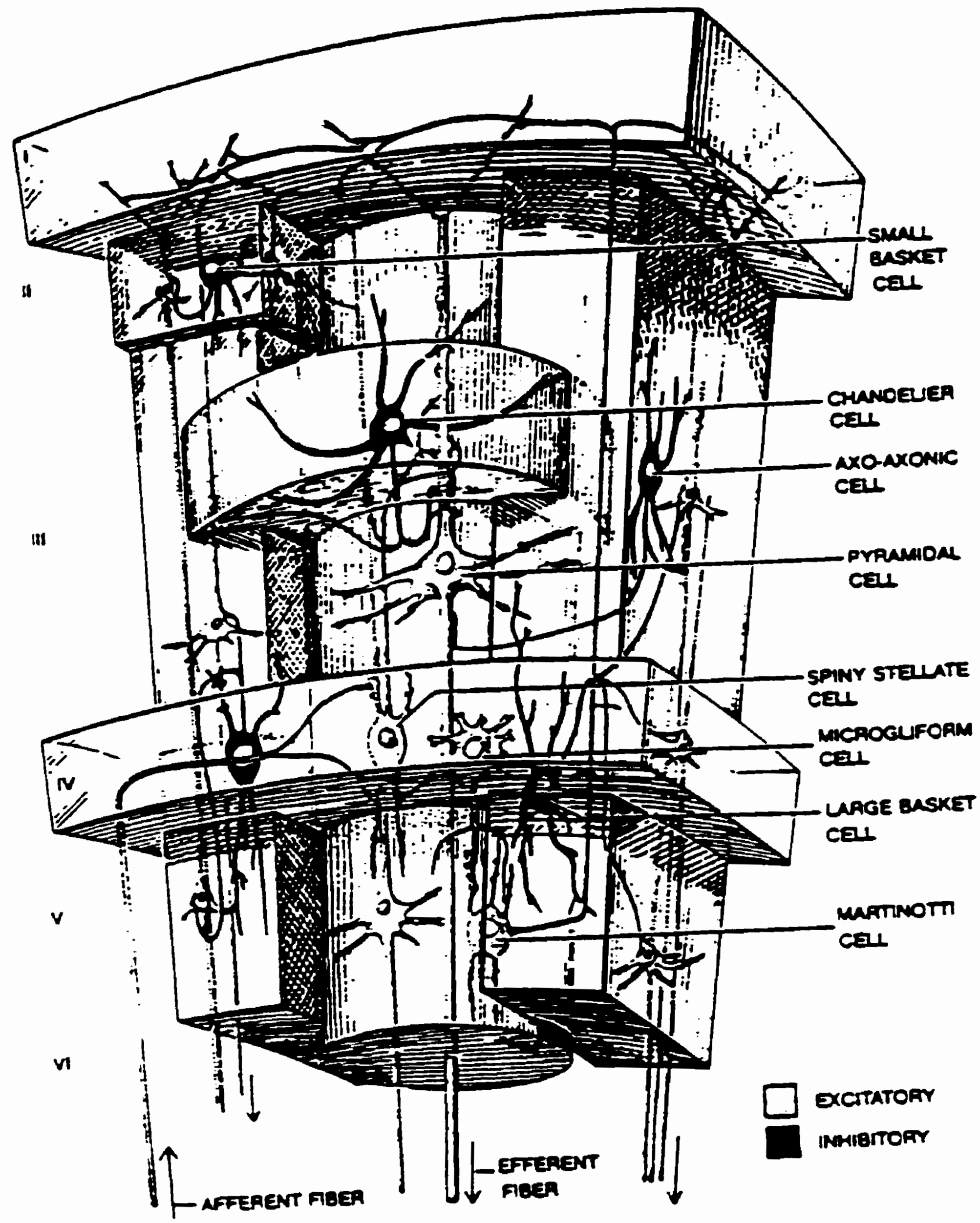


Figure 10. Sinatra's (1986) adaptation of Lassen, Ingver, and Skinhoj's cellular architecture of the cerebral cortex(1978), with diagram adapted from Janos Szemtagothai of the Semmelweis University Medical School in Budapest.. Neuro-scientist Paul Maclean (1978) proposes a theory of the triune brain which proposes a vertical organization of the brain in which information is processed through three particular, but associated areas which were called from bottom to top, the reptilian complex or brain stem responsible for primitive behavior, the limbic system, responsible for autonomic organ function , and the cerebrum or neocortex which governs rational thought and encompasses consciousness. Maclean proposed that the hierarchical arrangement of the layers represents separate evolutionary steps, over millions of years in the development of the human brain.

The cerebrum, the third layer of the brain and it's most recent evolutionary development accounts for 85% of the brain's size.. This newer brain operates at a level where thinking and consciousness can freely occur , while the earlier more primal brains perform the rudimentary functions of homeostasis. To increase the cerebrum's capacity to process verbal and non-verbal thought this outer brain layer has furrows or convolutions which appear on it's outer surface. This five millimeter layer of nerve cells arranged vertically in six neural circuits interprets sensory information utilizing schematic representation of previously stored data and previously proven successful strategies for problem resolution. Hemispheric balance is achieved through the neural fiber systems that connect the different parts of the brain. The corpus calosum provides lateral connections, while other systems such as the reticular formation produce vertical connections with the lower brain stem. The cerebral cortex contains vertically organized columnar modules made up of vertically arranged circuits of nerve cells. Shown is a simplified version of a column measuring 250 micrometers in diameter. Hundreds of incoming nerve fibers carry sensory information which converges on the spiny stellate cells in Layer IV of the cortex. The vertical circuits of interneurons, arranged in highly specific spatial configurations, transforms the raw data into conscious experience and behavior. While a limited number of neurons are shown to simplify the illustration of the cellular architecture, there are approximately ten billion neurons compacted inside this rational part of the brain, each of which is interconnected through dendritic networking. [From Sinatra, 1986.]

While anatomical and *electrophysiological research,* in concert, can explain the way in which *cortical cells* respond and presumably *encode* visual information these fields of inquiry cannot explain how the *receptive field properties* of cells relate to the way in which human visual perception is formed(Spoehr & Lehmkuhle, 1982). The study of *sensory psychology* is incomplete if it fails to consider the uses to which sensory information is put or the relationship between sensory and cognitive issues. Conversely, cognitive psychologists should be aware of the types of information supplied by sensory processes to the memory and problem solving systems (Spoehr & Lehmkuhle, 1982). There is an apparent conceptual gap between the study of the visual system at the sensory level and more cognitive approaches within the field of psychology (Spoehr & Lehmkuhle, 1982).

If we want to understand human visual *perception,* we must not restrict our study of the visual system to the part that performs sensory analysis(Spoehr & Lehmkuhle, 1982).

Some insight into the nature of *visual processing* has been attempted by combining the anatomical and electrophysical fields of inquiry with a third, where *psychophysical approaches* have been used to investigate human perception. Each of these three fields of inquiry focuses upon a particular feature of the visual system. Anatomy examines structure, electrophysiology examines response dynamics, and psychophysics examines function. Any valid explanation of how the visual system converts light energy into a visual percept should incorporate the findings of all of these approaches (Spoehr & Lehmkuhle, 1982).

The psychophysical approaches investigate function during pattern recognition using sensitivity experiments that (a) test for threshold reaction time, (b) isolate the dynamics of visual mechanisms through techniques such as visual masking, selective adaptation, and subthreshold summation, and, (c) apply orientation manipulations, binocular stimulation procedures, and random dot sterograms to grossly subdivide the visual system into central and peripheral stages (Spoehre & Lehmkuhle, 1982). An overview of these three fields of inquiry is described to provide a working knowledge of the structure of the visual system.

Structure of the visual system

To explain how the visual system converts light energy into visual perception the findings of three field of visual information processing research must be examined (Spoehr & Lemkuhle (1982). Each of these three approaches contributes substantially to the overall knowledge of the visual system. Anatomy emphasizes structure, electrophysiology emphasizes response dynamics, and psychophysics emphasizes function.

Anatomical approaches. Intact visual hardware (without or with corrective lenses) is a requirement for subjects in this study. It is assumed that the eyes function accurately. The following overview provides a working knowledge of the visual mecanism. Visual perception occurs when light radiating from a source is reflected by an object and focused by the eye onto a matrix of photoreceptors that convert the light energy into electrical signals which are carried along neural pathways and neural structures and individual nerve cells to the visual cortex (Spoehr & Lehmkuhle, 1982).

The major function of the eye is transduction, the conversion of light energy into nerve impulses. A second important function is accommodation, a reflexive process of the lens changing its shape to keep a fixated stimuli in focus. The external hardware of the eye includes the sclera, iris, pupil, six muscles attached to the globe of the eye and the cornea. The interior hardware of the eye includes the anterior chamber, lens, zonula, retina containing the photoreceptor cells called rods and cones, the fovea and the optic disc, and the optic nerve.

The cornea, a transparent covering on the front of the eye refracts light rays to focus them onto the back of the eye. The iris is a circular muscle that controls the amount of light entering the eye by contracting and relaxing. The transparent lens is held in tension by a membrane called the zonula and can readily change its shape by contracting or relaxing ciliary muscles to control the amount of refraction. During this process of accommodation not all stimuli in the visual field of view are in focus simultaneously. For example fixating on near objects result in distant objects being blurred because their image falls somewhere beyond the retinal plane and visa versa when fixating on distant objects.

It is in the retina that light is converted to electrochemical energy enabling the brain to interact with the external world (Spoehr & Lehmkuhle, 1982). The fovea, a shallow depression in the retina contains the photoreceptors and is the most sensitive area of the retina for resolving fine detail. The photoreceptors in the retina point away from the incoming light toward the back of the eye facing the choroid membrane, which is dark and absorbs the light not absorbed by the rods and cones. The retina in inverted therefore the light is diffused by the neural tissue including the ganglion cells in front of the photoreceptors causing a decrease in the sharpness of vision everywhere in the retina except the fovea. The optic disc, also known as the blind spot in the visual field because it does not contain photoreceptors is the point at which nerve fibres exit. The retina is composed of different types of cells among which are two types of photoreceptors, rods and cones distinguishable by their shape and the type of photopigment they contain. The photopigments absorb the light energy converting it into electrochemical nerve impulses. Four photopigments exist. The pigment in rods is efficient at low-luminance levels and is highly efficient at converting light energy to electrical energy. Each of the three pigments found in the cones form the basis for color perception as they are responsible for absorbing light containing the following wavelengths or colors: red, green, and blue. The electrical impulses of these photoreceptor cells enter a matrix of retinal cells where processing occurs prior to reaching the ganglion cells the nerve fibres that exit the eye through the optic nerve at the optic disc.

The neural pathways are collections of nerve fibres of cells which channel information to the neural structures in the brain (see Figure 11). These include the axons of the ganglion cells which depart the eye through the optic nerve at the optic disc.

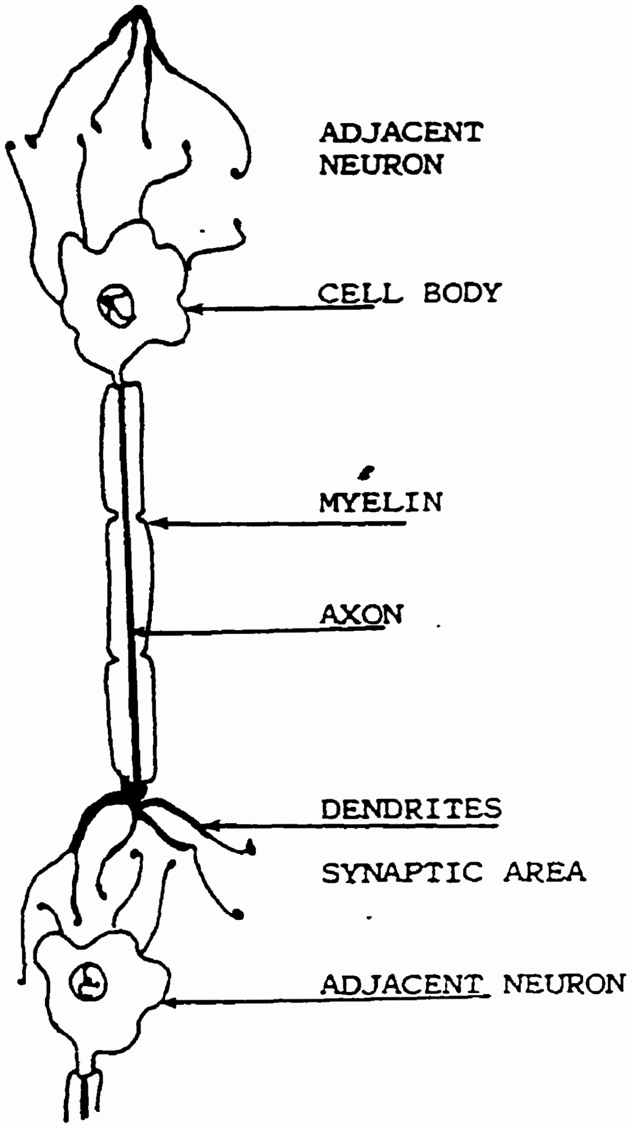


Figure 11. Sinatra's (1986) illustrated neuron and means of synapse. The neuron is the basic functioning unit of the brain. The neuron is a complete cell body which develops a connection to other neurons when a projection called the axon grows from the cell body of the neuron and upon the axon threadlike structures called dendrites emerge to form an axonal/dendritic network that allows neurons to connect with the dendritic growth of other neurons so that by maturity a single neuron may be transmitting and receiving informatiion from hundreds of other neurons. The axon conducts impulses from the neuron to the dendrite. To facilitate the electrical impulse transmission an insulating coating called the myelin sheath forms through a process of nerve fiber maturation called myelination. Myelination occurs in stages, with rapid growth occurring between the ages of 2 and 7 years, which correspond with Piaget's landmarks in cognitive development. The gap between neurons and dendrites where chemical transmission of information passes from one neuron to the next is called the synapse. [From Sinatra, 1986.]

The nasal ganglion axons cross at the optic chiasm travelling to the opposite side of the brain. The temporal ganglion axons stay on the same side of the brain. As a result of this partial crossing of ganglion cell axons, what the right eye sees is represented in the left hemisphere and what the left eye sees is represented in the right hemisphere of the brain. The information from the two eyes is combined in the visual cortex. This visual information travels to the cortex by one of two routes; the geniculo-striate pathway or the tectocortical pathway (see Figure 12a).

The neural structures in the brain called nuclei, are the processing centers of the visual system and include; the lateral geniculate nucleus which connects to the ganglion cell fibres in the geniculo-striate pathway and projects onto cells in the visual cortex, the superior colliculus where the tectocortical pathway's ganglion fibres terminate, and the pulnivar nucleus onto which the cells of the superior colliculus are projected and in turn projected to the visual cortex (see Figure 12b). Spoerh and Lehmkuhle (1982) cite Diamond (1976) and Berkley and Sprague (1979), indicating that while both pathways carry information from the eye to the brain, the geniculo-striate system has a vital role in processing information carried by small spatial details, coding shapes, and depth perception.

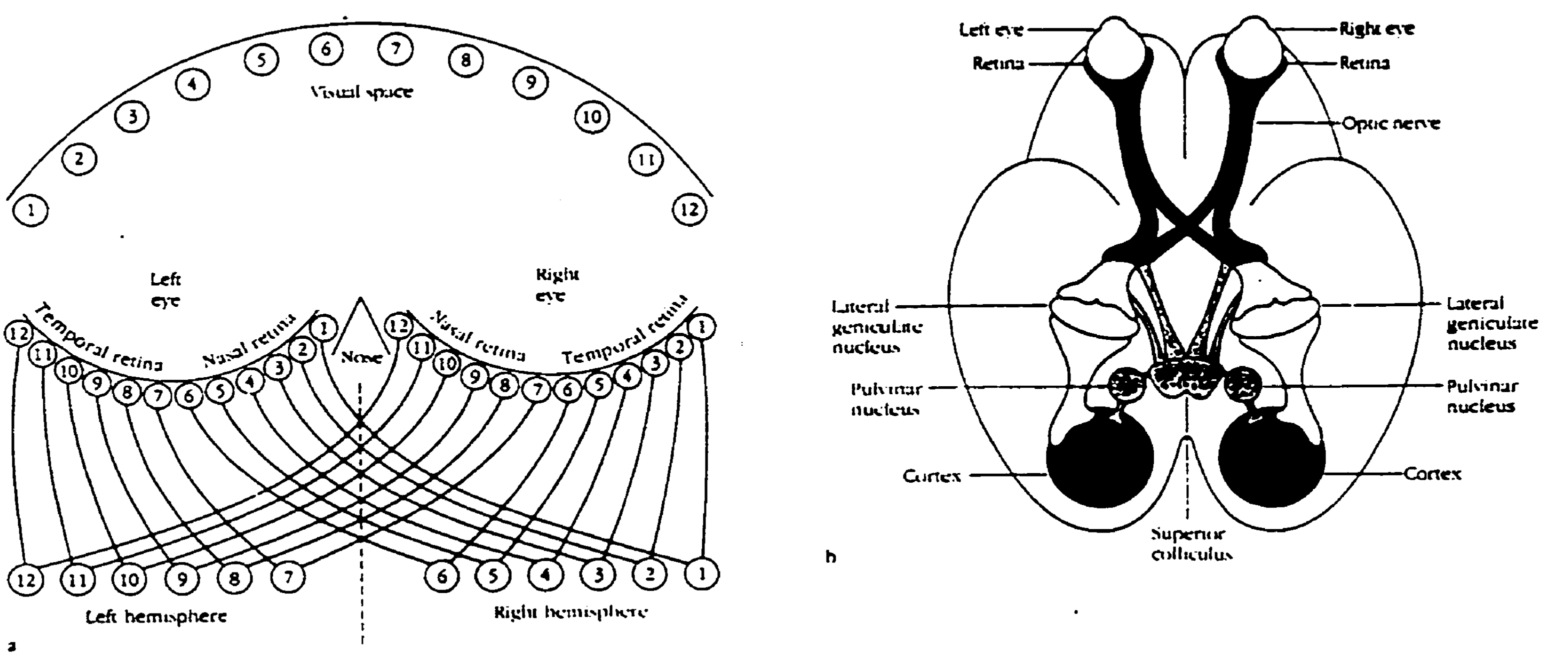


Figure 12. Spoehr and Lehmkhule's (1982) (a) Schematic illustration of crossing ganglion cell fibers and (b) Schematic illustration of the geniculo-striate and tectocortical pathways. In (a) axons for the same parts of the visual field are routed to the same hemisphere. Axons of the ganglion cells of the nasal retinal of the left eye terminate in the right hempsphere of the brain, and axons of the ganglion cells of the nasal retina of the right eye terminate in the left hemisphere of the brain by crossing at the optic chiasm. The axons of the ganglion cells in the temporal retina remain on the same side of the brain as they do not cross at the optic chiasm. The result of this partial crossing of ganglion cell axons is that the right half of the visual field is represented in the left hemisphere and the left half of the visual field is represented in the right hemispere. The visual field shown is divided into 12 regions. The left visual hemifield (regions 1-6) falls on the nasal retina of the left eye and the temporal retina of the right eye, and the right visual hemifield (regions 7-12) falls on the nasal retina of the right eye and the temporal retina of the left eye. In (b) visual information from the retinas is carried to the visual cortex by the geniculo-striate and tectocortical pathways. The geniculo-striate pathway includes the retina and geniculate nucleus. The tectocortical pathway includes the retina, superior collicus, and the pulnar nucleus. In the geniculo-striate pathway, ganglion cell fibers connect to the layeral geniculate nucleus, the fibers of which then project onto cells in the visual cortex. This pathway is believed to be an important processor of information garnered from small spatial detail, coding of shapes and depth perception. In the tectocortical pathway, ganglion cell fibers terminate on the super colliculus, a nucleus whose cells then project to the pulvinar nucleus which finally projects to the visual cortex.. If one of these pathways is destroyed , visual information is transmitted from the eyes to the brain by the remaining pathway. When both pathways cease to function, blindness occurs. [From Spoehr and Lehmkuhle, 1982.]

Electrophysiological approaches. The brain processes visual information through single nerve cells, called action potentials which have a baseline of activity or spontaneous activity. Encoding of visual information occurs when the frequency of the activity is either increased or decreased by stimulating the ganglion cell. Different ganglion cells responds to light in specific areas of the retina when it is stimulated by light. A cell's response region is called its receptive field.

Cells respond or encode light information in a variety of ways dependent upon the type and function of the cell. Most ganglion cells in the retina and cells in the geniculate nucleus have circular response fields, are monocular as they are activated by stimulation of only one the two eyes and respond in one of the following ways: (a) increased activity when certain wavelength light falls within their receptive field, (b) respond to spots of light and vary according to whether the spot of light is small or large, (c) sustained activity throughout the entire time the light is present in the receptive field, and (d) respond with transient bursts of activity when light is first turned on or off (Spoehr & Lehmkuhle, 1982, Kuffler, 1953).

The cells in the visual cortex have elongated receptive fields, are binocular and respond to stimulation either equally or to some extent from either eye, and respond best to slits of light with some cortical cells preferring lines of moving light that are either moving in a particular direction or are of a certain length (Spoehr & Lehmkuhle, 1982, Hubel & Wiesel, 1962). Representative maps of cortical receptive fields are shown in Figure 12b.

A limitation to the theories of anatomical functioning of the visual system as presented by Spoehr and Lehmkule is that many of the studies cited utilized mammalian subjects such as cats and monkeys and the findings of these studies may have been grossly overgeneralized to the human population.

Pshychophysical approaches. Psychophysical procedures can be utilized to measure sensitivity or the visual threshold of a stimulus and can provide information about the location and method by which visual information is processed.

Several of the widely accepted psychophysical techniques utilized in experiments to study perception in human beings are measures of visual sensitivity including: (a) visual threshold and reaction time (visual masking, selective adaptation, subthreshold summation), and (b) locus of processing (Spoehr & Lehmkuhle, 1982). First, measurement of visual threshold is studied by altering some aspect of a stimulus such as illuminance, contrast or size and recording the subject's response to that change. In response, the subject must adopt a criterion to help decide when the stimulus is present and when it is not. Data analysis techniques have been developed, based on the theory of signal detectability (TSD) that can separate the absolute threshold from the subject's criterion (Spoehr & Lehmkuhle, 1982).

Second, measurement of reaction time sensitivity, or how quickly a stimulus is seen, and how long it takes to process and recognize a stimulus can be obtained by presenting a stimulus well above the threshold and measuring the time which elapses before the subject reports its presence. Reaction time experiments have shown that the reaction time to horizontal bars is faster than the reaction time to oblique bars, even when luminance, contrast, and size are held constant (Olsen & Atteneave, 1970). This suggests, as with the threshold experiment findings, that horizontal and oblique bars are processed by different neural mechanisms with different sensitivities (Spoehr & Lehmkuhle, 1982). To further explore the hypothesis that different cortical cells are maximally sensitive to different orientations three methods are widely used. They include: (a) visual masking, (b) selective adaptation, and (c) subthreshold summation.

In visual masking studies, two stimuli are presented in proximity in space and time. A destructive interaction can occur between the two stimuli (Werner, 1935) where the mask interferes with the detectibility of the target. The temporal properties of visual masking provide evidence that there are limits to the rate at which information can be processed because, when the visual system mechanism is overloaded, some information is lost reflected in the reduced detectability of the target (Spoehr & Lehmkuhle, 1982). The amount of masking is greater when the target and mask have similar orientations than when the target and mask have different orientations (Houlihan & Sekular, 1968; Gillinsky, 1967). This implies that masking has greater interference when the two stimuli are processed by the same mechanisms, such as those for horizontal and vertical orientation (Spoehr & Lehmkuhle, 1982).

Selective adaptation occurs when a subject is required to fixate on a stimulus that is well beyond the threshold during a long inspection period (1 to 10 minutes). After this inspection period a second stimulus is introduced to activate the fatigued mechanisms and to obtain a higher threshold for the second stimulus. If the threshold for the second stimulus is not higher than the first stimulus, then it is assumed that different mechanisms were activated by each stimuli(Spoehr & Lehmkuhle, 1982). Findings of selective adaptation experiments conducted by Blakemore and Campbell (1969) also provide evidence to suggest that horizontal and vertical contours are processed by different neural mechanisms.

Subthreshold summation is a technique which uses the increase in sensitivity or reduction of threshold as a dependent measure. It differs from visual masking and selective adaptation which measure sensitivity loss. In subthreshold summation, the subject is presented simultaneously with two stimuli, the background stimulus that is below the threshold and the target stimulus. The threshold of the target stimulus is then measured. Findings of these experiments show that when both stimuli activate the same mechanism, the background stimulus acts as an enhancer for the detection of the target stimulus. The information from both background and target stimuli are summed by the visual mechanism and the threshold for the target stimulus is lower than when the target is presented alone. When the two stimuli are processed by different visual mechanisms, the threshold for the target stimulus is not affected by the presence of the background stimulus (Kulikowski, Abadi & King-Smith, 1973).

Third, psychoanatomical techniques inferentially subdivide the locus of processing for the visual system between peripheral and central stages of processing. Peripheral stages include all subcortical sites, such as the retina and lateral geniculate nucleus. The central stages include all the cortical areas. Behavioral work includes a number of psychophysical techniques to identify whether a given visual effect is the result of peripheral or cerebral mechanisms . These are orientation and grating, interocular effects, (Blakemore & Campbell, 1969), binocular effects (Blake & Levinson, 1977; Turvey, 1973), and cyclopean stimulus found in random dot stereograms (Vernoy, 1976; Julesz, 1971).

Orientation and grating. Findings of locus of processing studies show the centrality of visual processing. The affect is demonstrated in tests in which the orientation of grating patterns is changed. These grating patterns consist of a series of black and white bars (similar to a bar code) or squares (similar to a checkerboard). The magnitude of selective adaptation, when the target grating is orthogonal to the inspection grating results in no threshold elevation. This is consistent with earlier findings which show that cortical mechanisms are sensitive to changes in orientation whereas peripheral mechanisms are not.

Interocular effects. Further, this grating adaptation effect exhibits interocular transfer when the inspection grating is viewed only by the right eye and the test grating is viewed only by the left eye at the same time. The adaptation effect is transferred to the central stage because input from two eyes is not combined until the input reaches the visual cortex. Therefore, this interocular transferred is presumed to involve the fatiguing of central mechanisms. Similarly, studies show that visual threshold and subthreshold summation effects involve central binocular mechanisms because a patterned mask presented to the right eye interferes with the detectability for the target stimulus presented to the left eye. In addition the threshold for the detectability of target stimuli presented to a single eye, in the presence of a grating pattern mask presented to the other eye, is lowered.

Binocular and cyclopian stimulus. Random dot stereograms have been used to illustrate binocular properties of the central stage of visual processing. Separate dot stereograms which alone do not contain a visible pattern, but when combined create one, are presented to each eye (also known as a cylopean stimulus). To see the stimulus pattern the eyes must interact to provide a correlation of the information for the visual mechanism. The response to the cyclopean stimulus originates at the central stage of visual processing where stereoscopic depth occurs and the stimulus is internally formed. It is assumed that if an effect cannot be induced by a random dot stereogram, then the site of the mechanism responsible for the effect resides either in the peripheral stage or requires the cooperation of both central and peripheral systems (Spoehr & Lehmkuhle, 1982).

Spatial Limits of Human Visual Perception

The human visual system is selective in its sensitivity to visual stimuli. There are normal sensory limits within which stimuli must fall in order to be detected by visual mechanisms. These include; spatial aspects, movement, depth, and distance (Spoehr & Lehmkuhle, 1982).

Spatial aspects include: (a) visual acuity or the ability to resolve small stimuli, and (b) the contrast sensitivity function (CSF), a measure of the resolving power of the visual system not only for small spatial details but also for size, orientation, and contrast. Normal visual acuity is clinically defined as the ability to resolve a stimulus of 1 minute of visual angle. A spatial CFS is a measure of the contrast sensitivity to sinewave grating patterns for different spatial frequencies. Contrast, refers to the difference between the light and dark points of the grating, and spatial frequency, refers to the width of the bars in the grating and is measured by the number of light and dark bars per degree of visual angle. High spatial frequency gratings have narrow bars whereas low spatial frequency gratings have wide bars.

Contrast threshold is the point at which the bar or target stimulus is no longer distinguishable from a homogenous field. If humans were equally sensitive to all spatial frequencies then the contrast threshold would remain the same at all spatial frequencies. However research shows that humans are more sensitive to intermediate spatial frequencies (5 cycles per degree) than either low spatial frequencies (1 cycle per degree) or high spatial frequencies (10 cycles per degree) (Spoehr & Lehmkuhle, 1982).

Movement, or the speed at which a stimulus travels, affects perception by reducing visual acuity. While the passage of fast moving stimuli can be detected, small spatial characteristics of the stimuli cannot. The slower a stimulus moves the greater the number of spatial characteristics that can be recognized. Movement affects the CSF by reducing sensitivity at high spatial frequencies but does not reduce sensitivity at low spatial frequencies (Kulikowski & Tolhurst, 1973).

Depth and distance are important aspects of the perception of three-dimensional patterns influencing perceived size and brightness, and the recognition of patterns. Research in this area has just begun (Spoehr & Lehmkuhle (1982). Only two dimensions, the horizontal and vertical, have a geometric basis in the flat image formed on the retina. While depth is not geometrically represented on the retina, stimuli have the ability to evoke the impression of depth because the retinal image, in addition to the stereoscopic view provides the following monocular cues concerning depth: (a) interposition (a near object partially covers a far object), (b) shadows or shading (the direction of shadows registers the relative depth), (c) aerial perspective (far objects contain less detail), (d) linear perspective (physically parallel edges converge with increasing distance), (e) texture gradients (surface density increases at further distances), (f) familiar and relative size (objects at far distances appear smaller), and (g) motion parallax (in the case of moving stimuli the relative directions and velocities of movement register the relative depths of objects in space) (Spoehr & Lehmkuhle, 1982).

Distance influences the visual processing system through size-scaling and simultaneous contrast. Size-scaling is performed to maintain a constancy of the perceived size of a stimulus across a variety of viewing distances. The perceived size of a stimulus remains constant despite changes in the size of the retinal image which changes with viewing distance. This occurs because either the perceived size of a close stimulus is scaled down or the perceived size of a far stimulus is scaled up , or both (Spoehr & Lehmkuhle, 1982). Gilchrist (1977), conducted a series of experiments on simultaneous contrast and reports that the perceived depth of a stimulus plays an important role in the perception of the brightness of a pattern. Changes in the perceived brightness of a stimulus of moderate intensity (grey) when it is surrounded by or adjacent to a second stimulus of either much brighter (white) or darker (black) intensity were noted.

Three approaches to researching the visual processing of sensory information have been discussed. Each emphasizes a particular aspect of the visual system. In addition to identifying major structural divisions of the visual system, anatomical studies emphasize structure and show that visual information passes along one of two neural pathways (geniculo-cortical and tectocortical) to the visual cortex.

Electrophysiological studies emphasize response dynamics and have shown that ganglion cells and lateral geniculate cells have circular receptive fields and are monocularly activated, while cortical cells have elongated receptive fields, are primarily binocularly activated, and are sensitive to orientation, direction of movement, length, width, and wavelength composition of a stimulus. Psychophysical studies emphasize function by employing techniques that can isolate the dynamics of the visual mechanism by; measuring threshold or reaction time, demonstrating the effects of visual masking, selective adaptation, and subthreshold summation, identifying peripheral and central stages of visual information processing through orientation manipulations, binocular stimulation, and random dot stereograms.

However these theories and approaches alone cannot explain some of the most common experiences that early years learners share in their failure experiences with reading and writing. The reasons for their inability to encode and decode orthographic systems remains elusive and the question of what causes the preemption of their pre-literacy skills development remains unanswered. An attempt to answer this question is offered by examining memory as a phenomenological process within the context of the HMM of learning proposed by van Heerden (1971) and Garbor (1943). The proposed VGM views learning as a chemical process, highly sensitive to spatial orientation which is believed to be regulated by a spatial orientation device analogous to a gyroscope. This VGM device, when brought under control by the subject, may result in a self-righting tendancy which may be trained through haptic stimulation and rehearsal strategies.

Holographic Memory Models

In short, the current literature on early years children's response to stimulus manipulation to gain control over memory processes provides limited clinical insight for future research. However cautiously the conclusions of prior investigations are viewed, there is some direction presented for future research to examine forms of holographic memory and the processes of mechanisms under which it is acquired, accessed and controlled.

A brief overview of seven widely accepted information processing models of memory is presented to provide a basis for the VGM as a hypothetical construct in this study. This anlysis of memory research compares and contrasts specific attributes for each of the seven theoretical models under discussion to illustrate variations within them. A chronology of holographic brain theory development provides a timeline for the evolution of holographic memory. A schema is introduced to discuss the principles of eight memory theories which pertain to holographic brain function. The VGM is introduced, nested within the models of holographic memory, and related to visual information processing in early years students while reading.

The literature reviewed is primarily descriptive and anecdotal with few empirical investigations specifically geared toward early years subjects. Substantial methodological limitations exist because sampling procedures and subject selection were not randomized in those studies relying upon volunteer subjects. In some instances, control groups were not used to determine if subjects' behaviors were dependent upon independent variables wre the result of some unknown factor. Instruments and assessment techniques in many studies may not have been technically adequate. Important pre-existing behavioral, academic, and social data were not described in most studies. There were no longitudinal studies having assessed the development of early years subjects' mental rotation abilities over time. This lack of longitudinal data, concommittant with a lack of appropriate control groups, made it impossible to infer that behavioral changes were related to treatment conditions were a result of the treatments or from some other condition such as developmental maturity. Many researchers failed to adequately describe the relationship between the ex post facto independent variables (letter and numeral reversals, inversions, and transpositions) and pre-existing factors in the subjects' learning.

<u>Holographic Theories of Memory</u>

Seven information processing models are discussed, representing the attempt of cognitive psychologists to account for the complexities of memory by postulating equally complex internal processes. Included are the multistore (Atkinson & Shiffrin, 1960, 1968), levels of processing (Craik & Lockhart, 1972), visual information processing (Spoehr & Lemkhule, 1982), visual sensory or iconic (Neisser, 1963), eidetic (Gummerman, Gray & Wilson, 1972), haptic (von Bekesy, 1960, 1967; Tinbergen, 1972) and holographic (Gabor 1949, 1961, 1969, 1998; van Heerden 1970; Pribram, 1969, 1971 1985, 1986, 1991, 1993; Griffith, 1968; Cavanaugh, 1975, Prideaux, 1998).

An eighth topic, the *virtual gyrostatic mechanism* (VGM) is postulated, proposed, presented and discussed by this researcher, as a contribution to the evolving model of holographic memory.

The multistore model of memory. Broadbent (1958) and Atkinson and Shiffrin (1968) adopted the view of the organism as a processor of information who actively transforms, reforms, recombines, and restructures information from the external environment. Three stages of processing are postulated: encoding, storage, and retrieval. There are three main storage devices which are conceived of as permanent structural components of memory and are viewed to be specific to information processing in humans. These are: (a) the *sensory register* (SR), which holds information from the environment in its original sensory form for two or three seconds before it decays or fades away, (b) the short-term store (STS), with a limited capacity to hold encoded information (for example a phone number) over a longer span

(15 seconds), and (c) the long-term store (LTS), a repository for information with unlimited capacity retaining information for a long period of time (days, months, years, or permanently) but subject to retrieval difficulties. Control processes maintain information in the STS and transfer information to and retrieve information from the LTS. Rehearsal is an example of a transient control process. Forgetting in this model of memory results when information is encoded inaccurately, stored ineffectively, or is inaccessible during retrieval. Within this model these three storage mechanisms are viewed as a set of fixed cognitive structures or anatomical structures within the brain. This hypothesis has not been substantiated empirically and requires future research. The multistore model is a static conception of memory which views memory as an entity or a system of entities (Donahoe & Wessels, 1980). The Gestalt characteristics of memory, such as memory being fluid, active, and constructive in nature (Bartlett, 1932) are ignored in the multistore model. Therein lies the need to explore memory as a set of complex processes.

The levels of processing model of memory. Craik and Lockhart (1972) in their *Levels of Processing Model*, suggest that the postulation of three memory stores is unnecessary if information processing is viewed as multi-leveled and simultaneous analyses of stimuli. In this regard, the incoming information is processed on a number of different levels which include a first analysis of physical or sensory properties with simultaneous or concurrent (Craik & Tulving, 1975) analyses on other levels, such as phonological properties, culminating in the final and deepest level of analysis, currently believed to be semantic in nature. Retention or remembering, in this case, corresponds to the depth of the processing with information that is processed semantically being retained longer. Brief retention results when information is superficially processed at the physical level. In this model, memory is dependent upon the level to which information has been processed rather than the storage of that information being allocated to a particular memory storage device. The advantage of this model is that the multiple processes can account for memory at least as well as the cognitive mechanisms in the multistore model without assuming that the observation of a specific behavior indicates that a particular structure has operated in a specified way to process information, that information is stored in a permanent anatomical structure, or that memory is a fixed entity (Donahoe & Wessels, 1980).

The visual system as an information processor. A hybrid model of memory, synthesizing the characteristics and principles of the two earlier models, has been proposed by Spoehr and Lemkhule (1982). In this model, there is a direct emphasis on the role of visual input in memory. The visual system as an information processor relates actively to input. It plays five active roles which include: transformation, reduction, elaboration, storage, and retrieval. The visual system transforms information from one form to another. For example initial light information is transformed into neural impulses, transmitted to the brain and returned to the eyes through a system of retinal circuitry that enables one to see an object. Information can also be reduced, a process viewed as a necessary function to prevent information overload (Spoehr & Lehmkuhle, 1982). Conversely, a third function that the visual system performs is to elaborate on information filling out details based on information stored in memory. The process of preserving information in memory is called storage and the process used to recall experiences and things from memory is called retrieval.

Important assumptions of the information processing approach include a sequential ordering of stages in which the time to complete a task is the sum of the times needed to perform each stage. The accuracy with which the task iscompleted depends upon the accuracy of each component. Implicit in the sequential ordering of the stages is that the output from one stage provides the input for the succeeding stage. With respect to time and accuracy, because each stage is dependent upon information from the preceding stage, the time taken to process each stage accumulates and errors made at subsequent stages will produce inaccurate input for latter stages (Spoehr & Lehmkuhle, 1982).

Spoehr & Lehmkuhle (1982) cite two caveats about the information processing approach. The first caveat implies that while each stage involved in information processing is depicted as a distinct rectangle in flowcharts, such operations do not necessarily take place in physically different locations of the brain at different times. They claim that there is little knowledge about the specific cerebral mechanisms which facilitate this complex cognitive process. However, evidence supports the idea that many areas of the brain work concurrently, rather than independently at different times. The second caveat suggests that the direction flow for information processing indicated on flow charts does not imply that input travels only in a linear, uni-directional fashion. It has been found that stages mutually affect one another, even between nonadjacent stages. The sensory and cognitive mechanisms utilized in the human visual information processing system consist of two qualitatively different types, the control processes and memory (Spoehr & Lehmkuhle, 1982). The control processes include transformation, reduction, elaboration, storage, and retrieval. Memory, a storage system which is neither physically localized nor isolated in the brain creates space where information is stored for subsequent use and is divided into three types, sensory information store, short-term memory, and long-term memory. The three types of memory are differentiated based on representation or the way in which information is recorded.

The sensory information store is capable of retaining information for less than a second and creates the sensation that a briefly presented stimulus lasts longer than it is actually present. While visual information processing originates with this short-lived type of memory, minimal processing occurs as information has not yet been interpreted. As a result, the short-term sensory information store (STSS) is not a reliable or permanent memory storage system. Short-term memory (STM) allows an individual to retain information for as long as the person actively attends to it; a period of several seconds or longer with rehearsal. Information is transformed to identify salient features. The long-term memory store (LTM) maintains permanent records of information without the need for constant rehearsal by generating a representation that retains information semantically. It is responsible for creating abstract knowledge, real-world knowledge, and the rules and operations used to process information.

Sensory memory. Sensory memory, described by Donahoe and Wessels(1980) is the brief retention of raw, unprocessed information at the receptor level when environmental stimuli first make contact with an organism. In humans this phenomena has been observed in the visual (Sperling,1960), auditory (Massaro, 1970) and tactile (Abramsky, Carmon & Benton, 1971) modalities, with the visual modality being the most thoroughly studied.

Visual sensory or iconic memory model. The existence of iconic memory was established through experimental procedures developed during the 1960's utilizing tachistoscope technology. In studies conducted by Sperling (1960), following a 1/20th of a second exposure to the stimulus (e.g. an array of letters)the subject was asked to report everything that was seen. The time required to report an entire array of nine letters was found to exceed the storage time for this sensory information. This finding led to the development of a partial report procedure designed to investigate whether subjects had actually seen and remembered more information than they could report before the memory faded away. Results showed that subjects were able to recall information from each of the three rows ofthe array, indicating that their memory of the items would have to include all of the letters that had been presented. It was this observation, that sensory information fades or decays rapidly, that became the basis for extensive inquiry. In particular the pursuit of a measure of the length or duration of iconic memory, the capacity of visual sensory memory, and the nature of the information stored.

Iconic memory duration which has been approximated at 250 msecs (Haber & Hershenson, 1973). But procedural variables such as the brightness of the display and characteristics of the visual field following exposure to the stimulus have been shown to affect length of retention (Dick, 1974; Turvey, 1978).

The measure of iconic memory capacity, is estimated as in excess of four or five letters but is at best tentative and fallible because it is limited to the experimental procedures developed to assess it. The information stored in iconic memory has been reported to be visual (Averbach & Coriell, 1961) and closely related to the physical characteristics of the stimulus such as color (Banks & Barber, 1977), size, shape, and brightness (Clark, 1969; Turvey & Kravetz, 1970; and von Wright, 1968). The visual nature of information in iconic memory is evidenced in studies utilizing interference effect procedures such as erasure (Dick, 1974; Kahneman, 1968 & Turvey, 1978). In studies conducted by Dilollo, Lowe & Scott (1973) and Schiller (1965), the erasure effect was obtained when the stimulus was presented to one eye and the mask was presented to the other eye, indicating that erasure occurs at a central rather than retinal level. Findings of the studies conducted on the physical characteristics of the stimulus, clearly indicated that simple information concerning color, size, shape, and brightness are involved in iconic memory Banks & Barber, (1977). In contrast, studies requiring subjects to recall visual stimuli using partial report procedures by differentiating between letters and numerals were found to be incapable of facilitating recall (Sperling, 1960; von Wright, 1970; Well & Sonnenschein, 1973). The interpretation of these findings suggests that the information stored in visual sensory memory must be processed at a deeper level before the visual discrimination of stimuli based on semantic properties can be made. Presumably, the effectiveness with which the subjects respond in these studies depends not only upon their iconic memory processes but also the recoding of the information into verbal format. The extent to which iconic memory processes, recoding processes, or the familiar nature of stimuli influence iconic memory experiments (Mewhort & Cornett, 1972) are not adequately addressed by these researchers, and requires future research to define iconic memory in precise terms and to determine the effect of familiar stimuli.

Recognition and recall in sensory memory. *Pattern recognition* is the process in which precategorical information is identified or categorized. This process compares the raw information in the sensory memory to the permanent information that the subject has acquired to create a match called a pattern. The effortlessness and automaticity with which humans recognize patterns belies the subtle complexity of the process involved (Donahoe & Wessells, 1980). Pattern recognition hypotheses include: (a) template matching, (b) feature detection (see Figure 13), (c) context, data driven and conceptually driven processing, (d) synthesis, (e) selective attention, (f) attention in serial and parallel scanning, and (g) data and resource-limited processes.

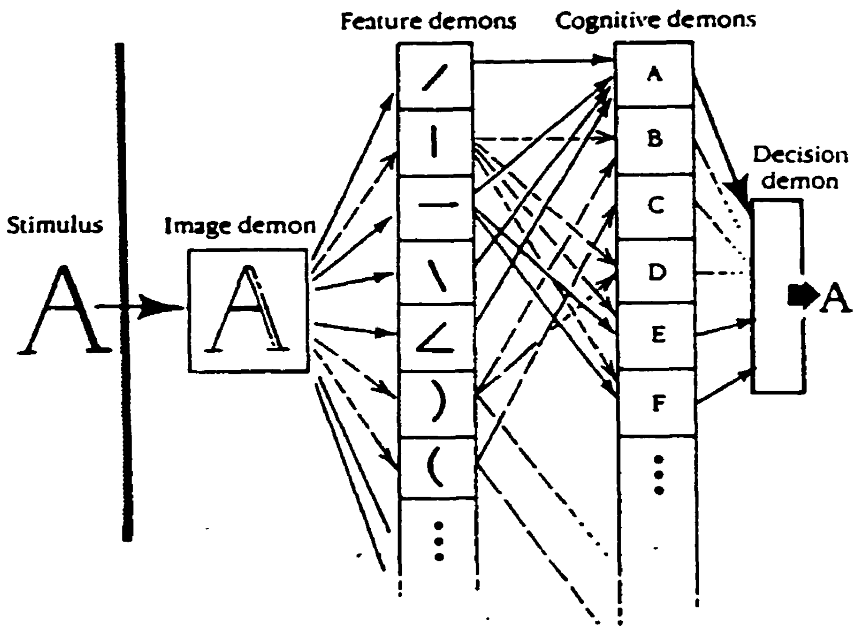


Figure 13. Spoehr and Lehmkuhkle's (1982) adaptation of Klatzky' (1980) schematic representation of the feature detection pandemonium model (Selfridge, 1959). Within this feature model, visual pattern recognition is viewed as a series of processing stages, using the term demons to describe the functional elements of each stage. Four types of demons are proposed, image demons, feature demons, cognition demons, and a decision demon. Image demons, the schematic counterpart to the physiological rod and cone receptors that transduce light energy into electrochemical energy, convert the light information imaged on the retina into electrical nerve impulses. Feature demons analyze the internal representation of the visual stimulus searching for particular stimulus characteristics such as orientation, length, width, color, angle, curve etc. Their physiological counterpart are the ganglion and lateral geniculate cells. Cognitive demons monitor the response of the feature demons while searching for a certain combination of features contained in the internal representation, analogous to a highly specific cortical cell in the highly visual inferotemporal cortex. The decision demon deciphers the activity of the cognitive demon and decides which cognitive demon is most active and indicates that the pattern has been recognized. In this way the information from all the visual cells flows to a comparator. Present understanding of the visual system does not include such a comparator which would be required to disentangle the responses of the cognitive demons. [From Spoehr and Lehmkuhle, 1982.]

The factors that facilitate or impair the retention of categorized information for brief periods of time have been the main foci of research on short-term memory (Donahoe & Wessels, 1980). A body of research indicates that the information in short-term memory can be encoded phonologically, visually, and semantically (Donahoe & Wessells, 1980). Other evidence indicates some support for olfactory (Engen, Kuisma, & Eimas, 1973), motor (Adams & Dijkstra, 1966), and spatial (Healy, 1974) formats. These formats represent contemporary conditions under which encoding has been observed to occur. It is accepted that there is no singular format responsible for encoding and that the ways in which biological factors contribute to the different encoding processes are not clearly articulated. The antecedents of encoding are currently unknown and thoughts concerning the phylogeny and ontogeny of encoding are speculative.

Researchers have demonstrated that information can be encoded, phonologically or in a verbal form by analyzing the types of errors subjects make when given visual stimuli and asked to record what they have seen. Evidence for phonological encoding was shown to depend upon prior experience with a tendancy toward verbal labelling and visual rehearsal during recall being evident for 10 year old subjects but not for five or six year olds (Hagen & Stanovich, 1974). The process of phonological encoding has been prevented in studies using verbal masks, with good recall of the visual stimuli, supporting the notion that other forms of encoding exist. Evidence for visual encoding is demonstrated in studies of mental rotation conducted by Shepard & Metzler (1971) and Cooper & Shepard (1973), where subjects were shown alphabetical letters rotated various degrees from the upright position, and asked to detect when the stimulus has reached the upright position and to indicate when the letter presented was a mirror image. Results indicate that reaction time increased with the difference in the angular departure of the letter presented from the upright position. The assumption that subjects formed an image of the test stimulus, rotated that image to the typical orientation, and then decided whether the imagined letter was normal has been supported in subsequent experiments (Cooper, 1975). Semantic encoding, has been debated in the research. Early research conducted by Baddeley & Dale (1966) failed to provide evidence to support semantic encoding during short-term memory encoding. Subsequent research conducted by Shulman (1970; 1971; 1972) Wetherick (1975) and Wickens (1972) observed the occurence of semantically based errors where subjects identified sematically related words as identical.

The most ubiquitous characteristic of short-term memory is lack of permancence (Donahoe & Wessles, 1980). The apparent, inevitable phenomena of forgetting recently learned information has been the focus of research which has found support for two theories of forgetting: decay and interference. With the decay theory, forgetting is viewed in terms of storage processes where memory loss is attributed to the gradual fading of stored information over time (Reitman, 1974; Shiffrin, 1973, Wingfield & Byrnes, 1972) and has been found to increase when rehearsal is prevented by a distractor task (Brown, 1958; Peterson & Peterson, 1959). Alone, decay theory, does not account for all forgetting as intervening events have been found to interact with decay to effect memory (Shiffrin & Cook, 1978). Interference theory, views forgetting in terms of retreival processes where memory loss is attributed to proactive and retroactive inhibition. Forgetting has been found to increase when when events preceding referred to as proactive interference (Loess, 1964; Loess & Waugh, 1967; Keppel & Underwood,1962) or following, retroactive interference (Dillion & Reid, 1969; Posner & Rossman, 1965; Watkins, Watkins, Craik, & Muzuryk, 1973) the learning of information hinder the subjects ability to recall that learned information. It is accepted that proactive interference is a major determinant of forgetting involving retrieval processes in short-term memory tasks. The precise mechanisms governing interference are merely speculative, with some inconclusive evidence derived from experiments utilizing procedures which were found to produce a phenomena known as release from proactive interference, where the similarity of test items in a series of consecutive trials were found to impair recall ability, whereas, for disimilar stimulus items, a higher rate of recall was reported (Gardiner, Craik, & Birtwistle, 1972). Another major determinant of forgetting is retroactive interference, which has been found to depend upon both the similarity of the information presented during the retention interval and the complexity of the processing tasks required to process that information during the retention interval (Crowder, 1975).

While two models of retreival are discussed, neither model can account for the complex information processesing of the human organism because there is no way of effectively differentiating encoding and retrieval phenomena (Donahoe & Wessells, 1980). One retrieval model in short-term memory, is serial processing (Sternberg, 1966). The serial process has been found to be exhaustive, where all items in a memory set are compared to a probe, rather that self-terminating, where the search would be expected to terminate once a match had been obtained. The occurence of this phenomena is attributed to a hypothesised two-step process involved in serial processing, where the exhaustive search, is completed first at a rapid rate prior to a decision being made about the probe. Whereas, with a self-terminating search, a decision would be made about the probe after comparing it to each memory set item (see Figure 14). Sternberg (1966) speculates that the time required to make comparisons is less than the time required to make decisions. Sternberg suggests that this can account for the observation that the same amount of time was required by subjects to identify a

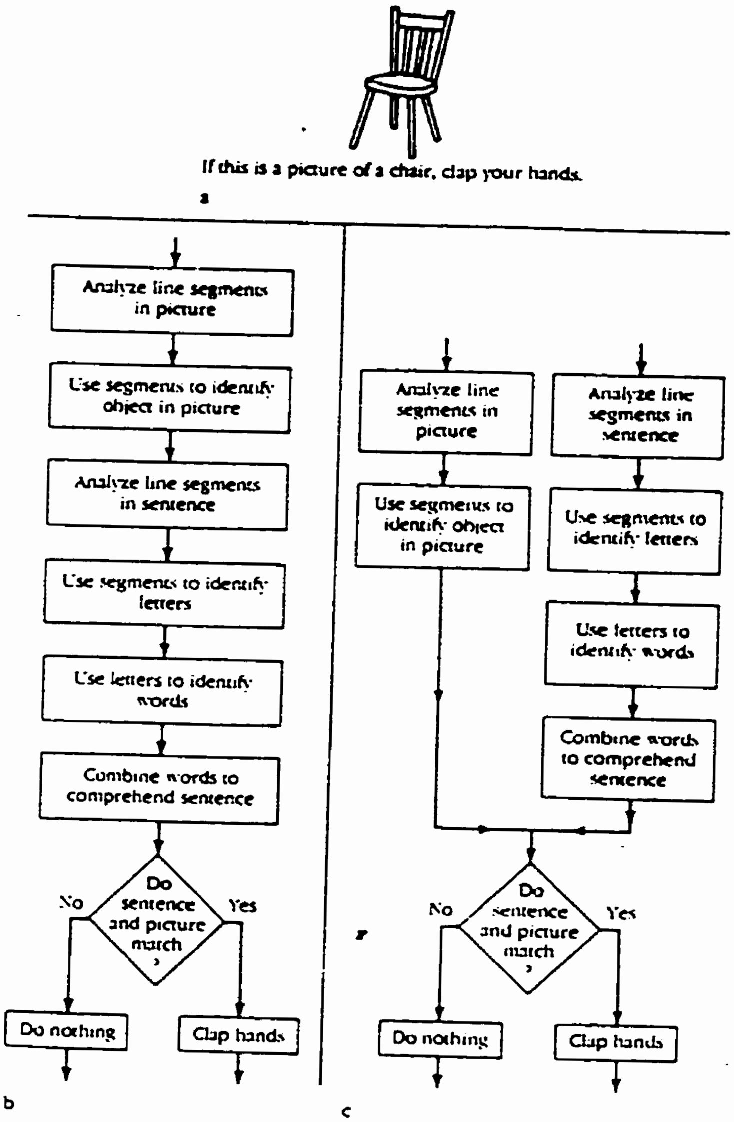


Figure 14. Spoehr and Lehmkuhle's (1982) flowchart of processing operations in a comparison task experiment. Using a computer analogy to understand the visual system as an information processor, the transformation of visual stimuli, reduction of information , elaboration of the information stored in memory, and storage and retrieval of information in and from memory are considered processing steps or operations. Rectangular boxes in the flowchart indicate discrete anticipated operations, while diamond-shaped boxes represent decisions. The arrows indicate the flow of information. Presented with the visual stimuli of the chair and sentence, the picture may first be recognized because it is on the top. It is recognized by identifying it's parts, back, seat, legs, and deciding it makes up a chair. In a serial sequence the sentence is processed next (b) by identifying line segments to identify letters, combining the letters to make words, combining the words and applying English grammar from memory to comprehend the sentence. The next step in the comparison task requires picture/sentence match to make the clapping response. Both picture and sentence could be simultaneously processed in a parallel process (c). Three assumptions of the information processing approach are illustrated here. Firstly, implicit in the sequential ordering of operations is the assumption that output from one stage is used as input for the next stage of the operation. Secondly, the amount of time necessary to complete a sequentially ordered task is equal to the sum of the times needed to execute each of the operations or stages. Thirdly, the accuracy of the completed task relies upon the accuracy of each of the component steps. [From Spoehr and Lehmkuhle, 1982.]

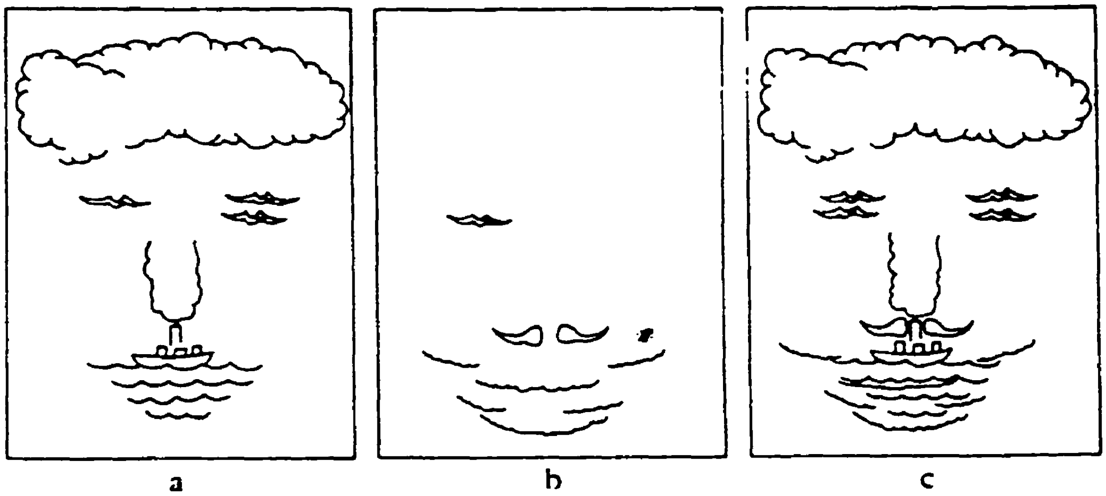
matching probe on positive trial as to determine no match existed on a negative trial. However serial position inconsistencies were reported by Sternberg (1975), which conflicted with the view that serial scanning is exhaustive. Reaction time has been found to depend upon the size of the memory set and the location of the matching item within the memory set (Burrows & Okada,(1971); Clifton & Birenbaum, 1970; and Raeburn (1974).

The serial-exhaustive retrieval model does not account for all types of scanning. Evidence has been found to support parallel processing. Subjects have been reported to scan for ten items as quickly as they could scan for one item (Neisser & Lazar, 1964; Sperling, Budiansky, Spivak, & Johnson, 1971). With this model, reaction time also increases as a function of the size of the memory set (Corcoran, 1971; Townsend, 1971).

Eidetic memory. Eidetic memory is a temporary form of visual memory, with photographic like properties, in that the individual is capable of retaining detailed and accurate visual images from complex visual stimuli for a period of about a week. Eidetic memory is refered to as imagery because the stimulus remains on the original stimulus plane rather than as a memory image. The cause of eidetic imagery is unknown (Tarpy & Mayer,1978). However, Spoehr & Lehmkhule (1982) cite Haber & Haber (1964), who suggest five criteria for determining whether an individual has eidetic imagery. These include: (a) an eidetic image persists longer than a typical perceptual afterimage, (b) eidetic images can be formed from low-contrast stimuli, while conventional afterimages need high-contrast stimuli, (c) colors are preserved in an eidetic image, (d) eidetic images can be formed by scanning the stimulus, rather than fixating on the stimulus, and (e) the eidetic image is stable, remaining in a fixed position while the eye scans the stimulus, while conventional afterimages move as the eye moves (see Figure 15).

Eidetic imagery has been studied among school children (Haber & Haber, 1964) who found eight percent of the subjects tested capable of forming eidetic images on picture description tasks. This study is descbribed in Tarpy & Mayer (1978). The subjects, 150 schoolchildren from New Haven, were instructed to look at a detailed picture from the book Through the Looking Glass (Dodgson, C. L., 1871) in which Alice is looking up at the grinning Cheshire cat who is sitting in a tree. The subjects were instructed to scan the picture by moving their eyes all around it in order to take in details. The stimulus was removed after 30 seconds and subjects were asked to keep moving their eyes over the space where the picture had been. Some children described the picture in complete detail for up to four minutes.

The phenomena of eidetic imagery cannot be explained by accepted theories of visual memory and may be relevant to the short-term memory store, considered to be the initial phase of perception and learning (Tarpy & Mayer, 1978).



An example of the pictures used in the superimposition test for eidetic imagery by Leask, Haber, and Haber (1969). When images (a) and (b) are superimposed, a face emerges (c) that is not obvious from viewing the two component pictures individually. [Courtesy of R. N. Haber.]

Figure 15. Pictures cited by Spoehr and Lehmkuhle from superimposition tests for eidetic imagery conducted by Leask. Haber, and Haber (1969). The formulation of the composte image (c) indicates an eidetic experience. The subject is exposed to images (a) and (b) in succession, which when superimposed in memory an image neither predictable nor apparent individually emerges to form a composite third image(c). Image (c) can only be visualized if the subject is able to form a true eidetic image of the first image (a), to mentally superimpose it upon the second image (b), resulting in the third composite image (c). [From Spoehr and Lehmkuhle, 1982.]

The incidence of eidetic imagery, is more likely in the preadolescent population (Spoehr & Lehmkuhle, 1982). Tarpy & Mayer (1978) cite Doob's (1964) explanation for the extremely rare occurence of adult eidekers - that society requires information to be encoded verbally rather than visually, and as the ability to read and write increases, the use of imagery falls.

Haptic memory. Memory acquired through the process of the touching experience, or sensorimotor interaction, is haptic memory. Also known as somatic memory, it is the earliest form of memory, developed initially during infancy when children are engaged in exploratory behavior for learning. According to Brierly (1994), touch "has a solidity that vision alone cannot give. Touch provides two or three independent checks about an object - movement, temperature, texture" (p. 77). Brierly (1994) cites an example, given by Tinbergen (1972), of a twelve month old boy who walked barefoot on both ragwort and thistles at the beach:

> "having moved over the ragwort without a reaction, he crawled over a thistle, with a start...he crawled on, then stopped and looked back over his shoulder...moving backward he moved his foot over the prickly thistle again...looked at it closely, touched the thistle moving his hand back and forth over it...then repeated the same procedure with a ragwort plant, touched the thistle once more and continued crawling" (p. 76).

Sensorimotor interaction with the environment develops the child's perception from seeing things as flat to seeing them as having depth and dimension. It also helps children to develop object permanence and to coordinate physical actions (Sund, 1976). Physical actions establish the basis for the development of mental actions (Piaget, 1954). Object manipulation helps the child develop representational thought, to see an object in the mind. According to von Bekesy (1963), the sensory experience of being touched creates a response which can be measured by mapping the "interaction between the patterns of energy change which excite the receptor surfaces and the spontaneously occurring neuronal potential changes of receptor units" (p. 1276).

The involvement of the hand in causing the brain to develop new representational systems for knowledge is examined by neurologist Frank Wilson (1998). Wilson's view of the hand surpasses the commonly held belief that the hand is a subservient tool of the brain. He proposes that the hand and the brain evolved in a partnership, with brain functions developing in response to the increasing demands of the hand as it explored the world around it. A theory of knowledge that incorporates both the brain and musculoskelature of the hand and arm to form a type of body intelligence is postulated. The hand within this new view functions as an explorer, discoverer, divider, joiner, enumerator, dissector, and assembler. Wilson claims that theories of intelligence which ignore the interdependence of hand and brain function and their effects on the evolving developmental dynamics in modern man may be misconceived. Wilson's manualcentric hypothesis encourages digression from the predominant cephalocentric view of defining the uniqueness of the human species primarily in terms of superior brainpower.

Holographic memory models. The holographic memory models popularized in the latter half of the tewntieth century are characterized by (a) the chronological development of abstract holographic theory (prior to the mid 1940's), (b) the mathematical proof of the postulated hypotheses (Dennis Gabor's physics interpretation of two-dimensional photgraphic holograms in 1945-1947), (c) the introduction of the technology to produce three-dimensional holograms (invention of the laser in 1964), (d) the production of the first three-dimensional holograms (by Leith and Upatneiks, 1965), (e) the application of holographic principles to human brain functioning (Pribram during the 1970's), and (f) subsequent empirical investigations supporting holographic brain theory.

According to Ferguson (1993), Pribram is:

> "credited by the literature in the field [of brain theory research] with launching a 'cognitive revolution'- the shift of scientific interest from behavior to thought...[Pribram's] holographic model attempts to marry brain research to theoretical physics; it accounts for normal perception and

> simultaneously takes the paranormal and transcendental experiences out of the supernatural by explaining them as part of nature" (p.70).

Pribram selected the hologram model, for memory storage. Ferguson (1993) states, "our brains mathematically construct 'hard' reality by interpreting frequencies from a dimension transcending time and space. The brain is a hologram, interpreting a holographic universe" (p.72). The neural strategies performed by the brain are complex calculations on the data it receives and have been described using mathematical computations. According to Ferguson (1993):

> "Pribram believes that the intricate mathematics may occur as a nerve impulse travels along and between cells through a network of fine fibers on the cells. The fibers move in slow waves as the impulse crosses the cell and those waves may perform the calculating function. In taking a hologram, light waves are encoded and the resulting hologram that's projected then decodes, or deblurs, the image. The brain may similarily decode its stores memory traces" (P.71).

A chronology of the development of holographic brain theory is presented in table form to provide an historical perspective on the research and development of holographic memory models (see Table 1).

Table 1

Chronology of Holographic Brain Theory Development

Date	Researcher	Theory Postulated
1714	Gottfried Wilhelm von Leibniz	-Discovers integral and differential calculus. Proposes that a metaphysical reality underlies and generates the material universe. Space-time, mass and motion of physics and transfer of energies are intellectual constructs.
1902	William James	-Proposes that the brain normally filters out a larger reality.
1907	Henri Bergson	-Proposes that the ultimate reality is a vital pulse comprehensible only by intuition. The brain screens out the larger reality.
1929	Karl Lashley	-Publishes his body of research demonstrating that specific memory is not to be found in any particular site of the brain but is distributed throughout.

Date	Researcher	Theory Postulated
1929	Alfred Whitehead	-Nature is an expanding nexus of occurences not terminating in a sense perception. Dualism such as mind/matter are false; reality is inclusive and interocking.
1947	Dennis Garbor	-Postulated mathematical formula for hologram. Used Leibniz's calculus to decribe a potential three-dimensional photography, holography.
1964	Emmett Leith & Juris Upatnieks	-Introduce modern holography, a radically new branch of optics.
1965	Leith & Upatnieks	-Popular article on holography published in Scientific American, to announce their successful construction of holograms with the newly invented laser beam.
1965	Karl Pribram	-Recognized that holography could provide a single conceptual framework to account for remarkable aspects of memory.

Date	Researcher	Theory Postulated
1965	Julesz, B. & Pennington, K.	-Propose that memory is stored within the brain as interference patterns compared to those used in holography.
1968	Longuet-Higgens	-Proposes Holographic Model of Temporal Recall.
1969	Gabor, D.	-Proposes Associative Holographic Memories Model to explain redundancy principle of brain functioning.
1969	Pribram	-Publishes first article on holographic memory, The neurophysiology of Remembering in Scientific American in which the ways in which the brain can exploit holographic principles is outlined. Fourier transform in holographic memory is proposed as the equivalent of the action potential in electrical impulse transmission neural activity. Proposes hologram as a powerful model for brain processes.

Date	Researcher	Theory Postulated
1970	Longuet-Higgens & van Heerden	-Proposes holographic model of the brain in an article published in Nature, Models for the Brain, in which they postulate that a neural holographic process exists to account for the extremely reliable and extremely fast form of information processing involved in singling a known face out from among a crowd, and the ability to recall significant amounts of information about that person once recognized.
1971	David Bohm	-Proposes that the organization of the universe may be holographic.
1973	Griffith	-Examines problems of memory and proposes holographic function of memory to explain how the function of a particular area of the brain can be assumed by a different area when the original site has been damaged.

Date	Researcher	Theory Postulated
1975	Cavanagh	-Examines formal aspects of cognitive processes and proposes two classes of holographic processes realizable in the neural realm.
1975	Pribram	-Synthesizes his theories and Bohm's in a German publication on Gestalt psychology.
1977	Pribram	-Publishes book, Languages of the Brain (1971), which outlines application of the holographic model to brain function. Speculates on the unifying metaphysical implications of the synthesis of his own, Bohm's, and Gestalt psychological principles.
1995	Oschmann & Oschmann	-Introduce soft tissue holography in somatic recall. Define somatic recall as the release, during massage, of highly emotional memories or flashbacks. Defines living matrix as an interconnected molecular continuum of living tissue.

Date	Researcher	Theory Postulated
1998	Bohm	-Proposes, a new theory of the relationship of mind and matter. Introduces term, holomovement which refers to the dynamic nature of the primary reality of the implicate order or enfolded order. Defines implicate order as the essential feature that the whole of the universe is some how enfolded in everything and that each thing is enfolded in th whole. Defines explicit order as the external relationships which are displayed in the unfolded order in which each thing is seen as separate and extended and related only externally to other things. The explicit order, which dominates ordinary experience as well as classical physics is secondary in the sense that it flows out of the implicate order. The holomovement or dynamic nature of the implicate

Date	Researcher	Theory Postulated
1988	Bohm cont.	order causes causes all things found in the unfolded explicit order to emerge from the holomovement in which they are enfolded as potentialities.
1998	Daily	-Applies holographic memory model to holographic memory release technique (HMR). Proposes an hypothesis for a healing model which promotes healing by accessing a body/mind communication network that is locked in a state-dependent, non-local field of holographic memory. The HMR technique utilizes the holographic principles of localization, coherence, intensity
1998	Prideaux	-Compares Pribram's, holographic brain theory to conventional models of neuronal computation to provide evidence for holographic brain theory and its importance in asking future research questions.

According to Ferguson (1993), Pribram is:

> "credited by the literature in the field [of brain theory research] with launching a 'cognitive revolution'- the shift of scientific interest from behavior to thought...[Pribram's] holographic model attempts to marry brain research to theoretical physics; it accounts for normal perception and simultaneously takes the paranormal and transcendental experiences out of the supernatural by explaining them as part of nature" (p.70).

Pribram selected the hologram model, for memory storage. Ferguson (1993) states, "our brains mathematically construct 'hard' reality by interpreting frequencies from a dimension transcending time and space. The brain is a hologram, interpreting a holographic universe" (p.72). The neural strategies performed by the brain are complex calculations on the data it receives and have been described using mathematical computations. According to Ferguson (1993):

> "Pribram believes that the intricate mathematics may occur as a nerve impulse travels along and between cells through a network of fine fibers on the cells. The fibers move in slow waves as the impulse crosses the cell and those waves may perform the calculating function. In taking a hologram, light waves are encoded and the resulting hologram that's projected then decodes, or deblurs, the image. The brain may similarily decode its stores memory traces" (P.71).

To fully understand the physiological experiments which provide evidence to support holographic brain theory, it is necessary to first explain the concepts of holography, the hologram, the holographic domain and Fourier transforms.

Holography is a word with a Greek derivative meaning complete writing, in that every part of the writing contains information about the whole. Holography is a well-known method of generating three-dimensional pictures (Dittmann and Schneider, 1992). It is an optical imaging process that records and then reproduces the entire image of a three-dimensional object and differs from photography. According to Pribram (1971), in photography:

> "the electomagnetic waves reflected or generated by the object are degraded by the lens of the camera and then are registered in a photographic emulsion that records a degraded image of the radiant object. In technical terms photographs only register the amplitude of the waves (brightness). In holography, the use of a coherent light permits the waves from the object to be registered directly as an interferogram (the interference pattern between two beams of light) and there is no degredation in the process. In technical terms, the hologram, equivalent to the impressed photographic plate, not only records and reproduces the amplitude of waves but also their phases" (p.1).

Lasers produce a coherent light source and have been in use since 1963 to generate holographs. This light is made up of waves that have the same wave length and the difference of their initial phase is conserved. According to Pribram (1986):

> "In holography the laser beam is split into two beams. The beam called the object wave, illuminates the object and is reflected onto the photographic plate. The other beam called the reference wave, does not cross any other media and it is aimed directly onto the photographic plate. The superimposition of the object wave and reference wave on the photographic plate produces an interference pattern, the hologram, which includes all the information of the original object. (see Figure 16). When an object is being reproduced, a laser beam similar to the original reference wave is directed to the hologram. Under these conditions the hologram scatters the wave and the observer perceives a reconstructed image of the original object" (p.2).

The holographic process produces holograms which have become popular features on credit cards, breakfast cereal boxes, magazine covers, diagrams in instruction manuals and portraits (Altman, 1992).

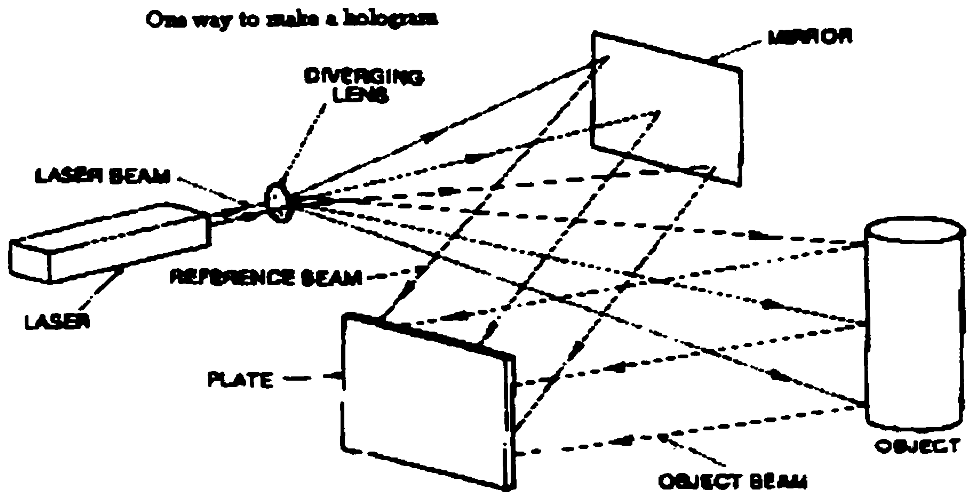


Figure 16. Prideaux's (1998) interpretation of Kasper and Feller's schematic for making a hologram. The holographic plate records an interference pattern between the diverged laser light and the scattered laser light bouncing off the object. The pattern recorded on the holographic plate is in the holographic domain. All parts of the holographic plate contain information of the whole. Light bouncing off each point on the object is distributed to every location on the holographic plate. There is a one-to-all mapping for the holographic plate. [From Prideaux, 1998].

According to Altman (1992):

> "A hologram is a piece of film that can generate the same light-wave information as is refelected from a real object. When you view the hologram it appears as though you are looking at a real object. The effect is so dramatic that you can see around the holographic image, shadows behind the image, and magnification of parts of the image if a lens was part of the original subject" (p.220).

The hologram is the material manifestation of a holograph. The physical hologram, first hypothesized by Gabor in 1946 was described using mathematical equations and existed in theory only within the domain of physics until the invention of laser technolgy in 1964, after which the first three-dimensional holograms were produced in 1965. The physical hologram is a photographic emulsion in which information about a scene is recorded. When the hologram is illuminated, a three-dimensional representation of the scene is viewed. In the event that the holographic plate were to be cut up into pieces, the whole image could still be extracted from any one of those pieces with some loss of clarity. In this way, restrictive damage to the hologram does not disrupt the stored information because it is has become distributed. Holonomy is a term Pribram introduces to refer to a dynamic or changing hologram.

Light is in the holographic domain before it gets transformed (focused) by a lense. Prideaux (1998) demonstrates this principle with the following two demonstrations that the light incident at the surface of a lense at any point is in a holographic form:

> "Take a pair of binoculars. Just look through one side focusing at a distant object. Now place your fingers in front of the lens so that only light coming from in-between your fingers enters the monocular. You will still see the whole image. If you bring your fingers together so that the light enters only through tiny slits, the whole image will still be present, only dimmer (and there will be some loss of resolution). If you rotate your hand, exposing the light to different parts of the lens, the whole image can still be formed...Remove the converging lens in a slide projector that forms the image. Place a slide in the projector and project the light onto a screen. No image will form. Technically, the light incident on the screen is in a holographic form. Each point on the screen is receiving information from every point from the slide. If a converging lens is place at a location between the screen and the slide projector, an image can be formed on the screen. The lens can now be moved to new locations in a plane cutting through the light

path to the screen and in each case a complete image is formed (Taylor, 1978)"(p.2).

The holographic domain where the spectral transformation of visual input takes place is specified by Pribram (1971) as:

"the arrival of impulses at neuronal junctions activates horizontal cell inhibitory interactions. When such arrival patterns converge from at least two sources their design would produce interference patterns. Assume that these interference patterns made up of classical postsynaptic potentials are coordinate with awareness. Assume also...that this microstructure of slow potentials is accurately described by the equations that describe the holographic process which is also composed of interference patterns. The conclusion then follows that information representing the input is distributed over the entire extent of the neural pattern" (p.152-53).

Prideaux (1998) defines the holographic domain for visual information more succinctly as the spectral domain to which images from the retina have been transformed. "The information in this spectral holographic domain is distributed over an area of the brain (a certain collection of cells) by the polarization of the variuos synaptic junctions in the dendritic structures" (p.14).

The silver grains on the photographic film encode the Fourier coefficients in optical holography. In holographic brain theory, the Fourier-like coefficients are stored as the micro process of polarizations and depolarizations occurring in dendritic networks at the synapses between the neurons.

Mathematically, a Fourier transform converts a function of time into a complex function of frequency. In this way a Fourier transform converts a signal from the time domain to the frequency domain. It can also be used to convert something from a spatial (coordinates in space) to a frequency domain. In the HMM it is proposed that the brain performs a Fourier-like transform for visual stimuli.

According to Prideaux (1998) the holographic memory theory proposed by Karl Pribram (1971) hypothesises that:

> "the dendritic processes function to take a spectral transformation of the episodes of perception. This transformed spectral transformation is stored distributed over large numbers of neurons. When an episode is remembered, an inverse transformation occurs that is also a result of dendritic processes. It is the process of transformation that gives us conscious awareness" (p.2).

The holographic memory hypothesis is based on the premis that neural representations of input are not simply photographic because, in addition to being composed of an initial set of feature filters, there also exists a special class of transformations, which resemble an optical image reconstruction process devised by mathemeticians and engineers, called holography. Holography uses interference patterns and can distribute and store vast amounts of information. Pribram (1971) proposes that holographic properties can resolve the paradoxes posed in brain theory research by the demonstrated anatomical constraints in neural input organization and explains why local lesions do not selectively impair memory. According to Pribram (1971):

> "optical information processing by holography is described mathematically in wave [electromagnetic] mechanical terms. In physical optics, the equations used to describe the behavior of light can be couched either in quantal [packets] or in wave form. The physicist...is concerned in describing the results of his observations as quantitatively and fully as can be done and chooses his descriptive tools accordingly. Some observations can be crisply described as statistical probabilities of occurrences of quantal events; others yield more readily to the mathematics of wave formulations" (p.141).

The holographic hypothesis of brain function in perception is based on a phenomena called *superposition*. Superposition is a process where a light wave influences the ones next to it and creates an interaction effect called interference.

The mathematical equations that account for superposition are called *convolutional integrals*, as they refer to the way in which a description of one wave form becomes convoluted with that of another. The brain's electrical potentials are described in wave mechanical terms to represent the shape of a stimulus figure. Pribram(1969) cites Rodiek(1965) on the retinal stimulation of cats, indicating that the interaction of convolutional integrals may produce hologram-like interference patterns in the visual system and elsewhere in the brain. The storage of these patterns can provide the basis of a distributed memory system (see Figure 17). The spatial interaction described by the convolutional integrals that define superposition facilitates the conceptualization of the interaction in terms of interference effects. Further evidence is found in the retina where neighborhood interactions in the horizontal cells are caused entirely by the inhibitory interactions of slow potential hyperpolarizations, and not as a result of the depolarizations that cause nerve impulses.

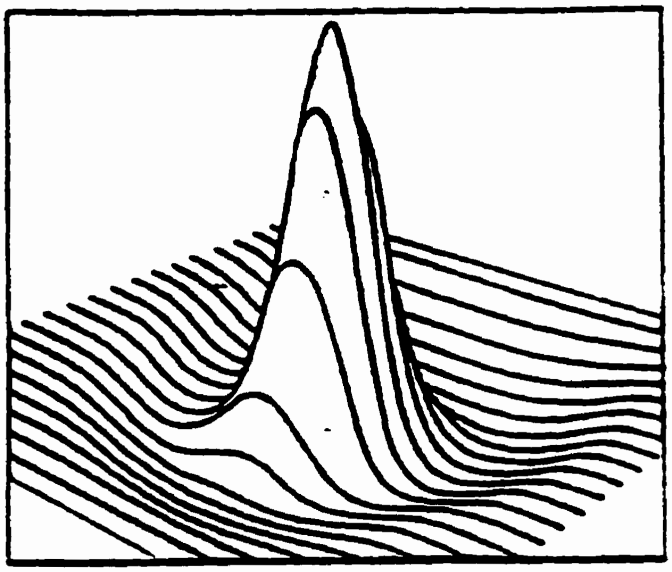


Figure 17. Pribram's (1969) interpretation of Rodieck's (1965) map of visual receptive field. This map of visual receptive field represents recordings from the axon of a single ganglion cell in the retina of the eye when a point source of light is presented. The map contains smooth contour lines because the ganglion cell integrates the response of its neighbours with which it is interconnected. In mathematical terms , each contour line represents the convolutional integral of the first derivative of the shape of the stimulus figure. The interaction of many such convolutional integrals may produce hologram-like interference patterns within the visual system and elsewhere in the brain. [From Pribram, 1969].

Receptor events are the basis of the neural holographic process. The excitation of one unit in the optic nerve affects the discharge rate of neighboring units. The receptive field of a given unit is composed of this spatial interaction among neighbors. The convolutional integrals that spell out the response relationships among neighboring events (spatial superposition) describe the basic process involved in holography, in optical information processing systems (Gabor, 1949, 1951). The physical process based on interference effects, or the *physical hologram*, displayssimilar attributes of the neural process in perception.

Models of Holographic Brain Function

Compelling evidence exists lending support to the *neurophysiological approach* of investigating brain function to explain memory and learning. This electrophysical information provides a basis from which to explore memory and learning beyond an educational context, from a biomedical position. Eight examples will be discussed to create a theoretical framework upon which the proposed virtual gyrostatic mechanism memory model (VGMMM) can be substantiated. A three stage octagonal web schema is used to illustrate these foundational brain theories as they pertain to holographic brain function at the macro, meso and micro levels (see Figure 18). The macro level represents the eight current theories, the meso level indicates applications to learning and memory which are consistent

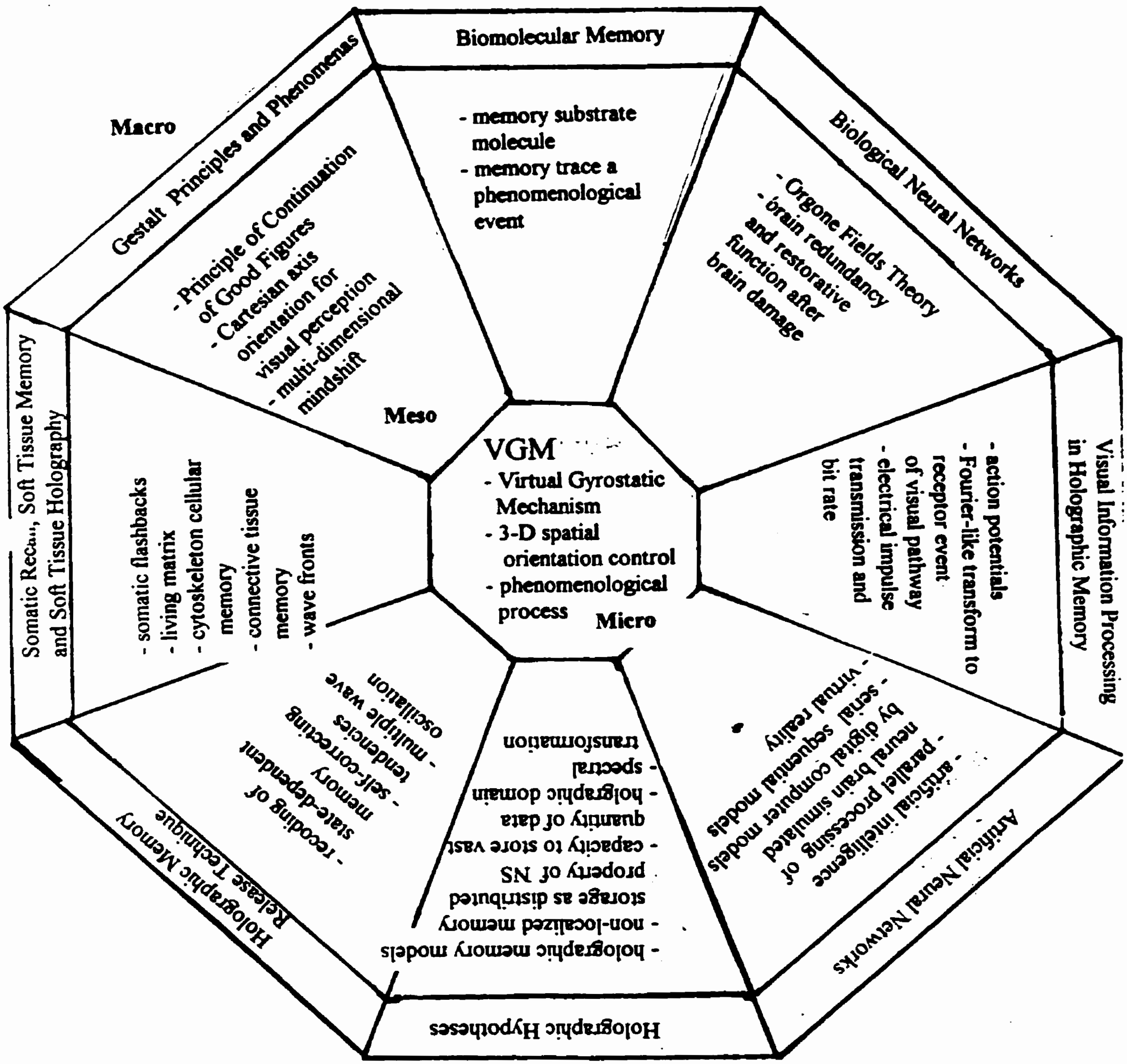


Figure 18. Octagonal Web Schema of underlying memory theories for the Virtual Gyrostatic Mechanism (VGM). Eight foundational biomolecular and electrophysical memory theories create the structural framework for the proposed VGM Each theory contributes specific characteristics which lend credence to the proposition that a three dimensional phenomenological process for memory acquisition and retreival may be under the control of a spatial orientation mechanism the VGM. The Octagonal Web Schema explores current brain research theory as it pertains to holographic brain function on three levels, macro, meso and micro. The macro level represents the proposed theory, the meso level indicates the application to learning and memory, and the micro level indicates the sustainability of the proposed VGM

with a three-dimensional phenomonological process for memory acquisition and retreival, and the micro level indicates the sustainability of the proposed VGM by specifying how the VGM may operate functionally within this hybrid environment. The current brain research theories which will be discussed are as follows. First, biomolecular memory theory will be used to explain how neurons behave in visual processing during information encoding, storage, and retrieval. Second, biological neural networks are discussed to explain ~~how~~ the brain ~~uses and stores~~ redundant information to regenerate some neural circuits after brain injury. Third, visual information processing in a holographic memory model is discussed. Fourth, the mathematical equations derived from artificial neural network algorithms modelled on digital computers to create artificial intelligence (AI) are used to suggest that the brain can process information within its parallel architecture. In addition, the role of the nonlinear property of neurons in in solving pattern recognition tasks is related to information processing in biological neural networks. Fifth, three holographic hypotheses are presented to provide a philosophical basis for holographic memory. Sixth, the possibility that state-dependent memory may be re-coded to move the individual to a greater point of self-sufficiency using a Holographic Memory Release Technique (HMR) is explored. Seventh, Pribram's model of holographic memory is related to the phenomenon of recall. Eighth, the Gestalt principle of continuation of good figures, and the phenomenas of multi-dimensional mindshift and Cartesian axis orientation provide data to substantiate the proposed VGM.

Biomolecular memory. The theories which view information encoding, storage, and retreival in the nervous system by a structural neural alteration process in the brain were upheld until the 1960s. According to Gurowitz (1969), in the late 1960's "a new type of theory has come into prominence which gives changes in brain chemistry a central role in memory storage" (p.1). This evidence for the chemical basis of memory and learning was gathered almost exclusively through animal studies because of the intrusive nature of the experiments. Two approaches were used. In the first, the experimenter "attempts to alter the metabolism (using electroconvulsive shock, hypothermia, and drugs) of a suspected memory substrate and then tests for the effects of the intervention on learning or memory" (Gurowitz, 1969). In the second approach, subjects were trained on a task and tested for effects of the training on brain chemicals. The brains of the trained subjects were injected into the brains of naieve subjects which were then tested on the same learning task to determine inter-animal transfer of intelligence.

Electroconvulsive shock (ECS) was found to interfere with memory by producing retrograde amnesia when the ECS was administered during a short time following learning. This led to the hypothesis described by Gurowitz as "there (being) a period, as of yet indeterminate length, immedialtely following learning when memory encoding is liable to attack by the disruption of brain electrical activity" (P.6).

The interface between short-term memory and performance is dependent upon continuous neural activity. Synaptic transmission is the logiqal site for this process to occur because of the chemical nature of the electical event of neurons firing. Genetic information is stored and transmitted chemically through dioxyriboneucleic acid (DNA), so it was proposed that learned information was stored in the same way. Two approaches to explain the chemical basis of memory are the molar and the molecular. The molar approach examines the synapse to detect changes that occur in memory and views behavior as the result of synaptic activity. The neural transmitter acetycholinesterase (ACh) levels and the displacement of calcium ions from the synapse by the acedic acid product of ACh hydrolysis have been proposed to have effects on memory. In this view "learning is facilitated by a decrease of calcium ion concentration at the synapse and retarded by an increase" (Gurowitz,1969).

The second approach to the chemical nature of memory is the moleular. Gurowitz (1969) cites Katz and Halstead (1950) who suggest that "neurons contain protein molecules in random configurations which become ordered by impulses coming into the neuron" (p.10). The search for the *memory molecule* examined nucleic acids and protein to identify a single potential memory molecule.

Gurowitz (1969), in a review of the literature on the chemical basis of long-term memory concludes that the memory substrate is macro-molecular in nature, but that the identity of the memory molecule is unknown. Neucleic acids and proteins were the focus of the early research. Neuclei acid studies cited by Gurowitz (1969), examined the work of early researchers who conducted studies primarily on animals to determine the role of DNA in memory.

Nucleic acids. DNA was the intial choice for investigation because of its role in the encoding and storage of genetic information. It was this information encoding function which created the belief that another function could exist on the DNA molecule. The pursuit of this hypothesis led investigators to find that:

> " narcotics and mechanical irritation of cells caused no change in DNA quantity...ECS had no effect on DNA metabolism......[there is] an extreme constancy of the amount of DNA [both within and between mammalian species]...DNA is extremely resistant to change from outside influences...there is no evidence that DNA, once formed, ever changes, or that the biosythetic process can be influenced by the sort of electrochemical processes occurring in nerve cells" (Gurowitz, 1969; p. 24).

The most influential finding was the stability of the DNA molecule with regard to environmental influences which caused it to be refuted as the memory molecule. By 1964, the inquiry for a single memory molecule shifted to another neucleic acid, riboneucleic acid (RNA). Subsequent theories of DNA involvement emerged as a result of the RNA findings which suggested that DNA may have a peripheral or subsidiary role in the DNA-RNA complex of new gene activation.

Early research on RNA as the memory molecule was explored by examining RNA metabolism during behavioral events, drug induced effects, and yeast effects. Metabolism studies involved changes in RNA levels as a result of drug induced neural excitation, neural inhibition, and learning at cellular and organismic levels. Drug research attempted to facilitate or inhibit memory, and concommittantly, the synthesis of RNA using drugs.

The data from these early studies resulted in the development of theories of RNA as the memory molecule. Three proposals which assigned a central role to RNA in the formulation of memory include; Hyden's (1960) RNA-specification Theory, Landauer's (1964) Membrane-tuning Theory and, Briggs and Kitto's (1962) Enzyme-induction Theory.

Hyden's early theory proposed a three-step intracellular machanism to create a memory trace. This theory naively assumed that there was a single memory molecule. His was one of the first and consequently best known molecular memory theories, even though Hyden's subsequent research caused him to refute his initial hypothesis in favor of a more complex theory involving DNA activation in the memory process. Gurowitz cites three problems with Hyden's hypothesis. First, "evidence from lesion and brain injury studies refutes the notion that one cell provides the locus of each memory" (p. 43). Second, the inability of nerve cells to regenerate and the fact that no new nerve cells form after birth places severe limitation on memory capacity. Gurowitz indicates that this process must be finite because while, "there are billions of nerve cells in the brain, there are also billions of bits of memory stored up in a lifetime, and one wonders how many cells might be allotted to one memory" (p.44). Third, to store the information encountered in a lifespan, "it would seem necessary for a given cell to have the capability of storing more than one memory trace" (p. 44). In view of these limitations, Hyden revised his theory in 1967 assigning a lesser role to RNA and including DNA and proteins as substances which may provide the memory trace in the RNA-DNA-protein complex theory described in the following discussion.

In 1964, Landauer proposed two hypotheses to account for for learning and retreival in biochemical memory. The learning hypothesis proposed a sequential process of large-scale transfer of RNA through the cellular membranes of glia cells to the neurons in which the information is stored.

The retreival hypothesis suggests that the neural membrane acts as a pass-band filter in which the currents spread from a neuron to adjacent tissue during conduction and that these expanding currents affect neurons with the same pass-band frequencies. The tuning of a membrane is determined by its proteins and, when the RNA passes from the glia to the neuron, the tuning is altered because the RNA-dependent protein synthesis is altered. Within these hypotheses, Landauer provides a means by which conditioning is viewed as a change in the selective sensitivity of single neurons. Lacking empirical support for Landauer's ideas, Gurowitz concludes that "what Landauer appears to have done is to set up a fairly plausible, although perhaps only partially testable, set of operations which might provide a mechanism for the changes proposed by Hyden in his early theory" (p.46).

In 1962, Briggs and Kitto proposed that memory was based in the concentration of certain enzymes found in neural tissue such as acetylcholine, the enzyme involved in the manufacture and breakdown of neural transmitter substances. This early theory provided a basis from which later research conducted by Flexner (1967) led to the development of a protein-oriented enzyme-induction theory.

Drug research examined the effects of chemically altering RNA to facilitate or inhibit memory. Based upon the assumption that RNA is the memory substrate, researchers sought to disrupt the metabolism of RNA using three drugs:

(a) 8-azaguanine which affected new learning, but not previously learned behavior, (b) actinomycin-D which was found to have no effect on forgetting learned behavior, and (c) magnesium pemoline, a CNS stimulant, which affects RNA production. Gurowitz cites a series of studies using magnesium pemoline for which Talland (1966) found improved accuracy on short-term memory performance on tasks requiring sustained attention for human subjects and concluded that the drug had an alerting effect enhancing attention rather than a direct effect on memory function. As a result of these early investigations, the effect of magnesium pemoline on RNA was dismissed because, while it does have short-term stimulant effects on attention, it does not improve learning, memory, or performance over the long-term.

Attempts to improve learning by increasing the quantity of RNA in the body by injecting solutions of RNA extracted from yeast into human subjects experiencing memory deficits and confusion are discussed by Gurowitz. He cites Cameron (1958; 1963) who attempted to improve memory impairment in aged patients. Cameron found that the RNA injections increased metabolic function and alertness and that the "memory-improving functions of yeast RNA, like those of magnesium pemoline may be due to a general stimulating or alerting effect" (p. 38).

This early research failed to provide data to support RNA as the memory molecule. The RNA metabolism studies demonstrated that neural RNA can be influenced by environmental occurrences. Drug studies showed that RNA metabolism and synthesis can be altered through sedative or stimulant effects, and increasing the quantity of RNA by injecting yeast RNA resulted in only stimulant effects.

Proteins. The first systematic theory of memory in which protein was veiwed as the memory molecule was proposed in 1950 by Katz and Halstead. They proposed an analogy between genetics and memory, in which memory was the result of the formation of new protein molecules that encoded memory in the same manner that genes encode hereditary data. The assumption that each gene was composed of one nucleoprotein molecule was upheld at the time of their research. As a result, Katz and Halstead erroneously proposed that the same application could be made to individual memories. They assumed that protein memory molecules would analogously read out memory, by forming protein latticeworks (distinguishable from each other by their chemical structure) that constituted the memory trace. They believed that neurons consisted of a random array of protein molecules that were inactive and incapable of conducting impulses until they were networked into a lattice. They proposed that the first impulse to enter a neuron rearranged the random proteins into an ordered array and enabled it to conduct impulses. The organization of the first neuron spreads to the adjacent neuron creating a neural network through the cerebral cortex until it encounters an already organized neuron. In this way memory traces may not be linear, but distributed from the first organized neuron in a variety of directions. According to Gurowitz, while dismissed as untestable experimentally, and founded on the invalid construct of gene composition, this theory on molecular memory was the first to suggest a memory mechanism "based on the core conductor view of the neuron, and to consider the membrane to be a semiconductor" (p.57).

In 1967, Flexner proposed a theory of long-term memory that proposed the establishment of a self-sustaining maintenance system for protein and nucleic acid molecules. Flexner hypothesized that memory is not dependent upon a particular memory molecule, but rather upon a self-inducing system for maintaining protein and neucleic acid synthesis.

Hyden (1967) proposed a RNA-DNA-protein complex theory which provides a mechanistic model of molecules for memory storage. The model has three stages; the activation of DNA cells by the sensory information, RNA synthesis which produces new protein to transmit the sensory input along neurons creating a neural pathway coded for this specific input, and the protein maintenance of these cellular changes.

While the memory substrate was not specified by these researchers during the 1950's to 1970's, the belief that a phenomenological event occurs in the formulation of memory still persists. In this way, the biomolecular research provides a basis from which to continue the exploration of memory on a macro-molecular level. Research in this field of inquiry continues with the exploration of the effects of the hormones serotonin and norepinephrine and a host of vitamin therapies for increased mental alertness and enhanced cognitive functioning. In the 1990's, pharmaceutical and homeopathic companies are investing millions of dollars in research and development in their competition to capture the market for brain and health enhancement remedies.

Once the attempt to realize a single memory engram became exhausted over a period of thirty years of empirical investigation, researchers turned toward investigating a more complex phenomenon of neurobiological models of memory A new view developed in the 1970's in which researchers sought to find the memory engram within the general protein metabolism of the nervous system and subsequently for specific proteins that may operate as memory molecules. Molecular memory transfer became scientifically untenable. However, the idea that highly specific proteins may be involved in memory formation led to future research involving the soluable protein of glial cells- S100 protein, the 14.3.2-protein, vasopressin and the synapse membrane protein (SMP) which were shown to have attributed specific properties associated with memory storage. This led to models for the formation of memory through molecular facilitation in synapses with gangliosides from the mid-1970's thru the 1980's.

Rahmann and Rahmann (1992) provide an overview of the most important steps involved in memory formation through molecular facilitation in synapses by gangliosides. Gangliosides in short- and long-term neuronal processes, are involved in molecular facilitation in synapses that is essential for the formation of memory tracks. According to Rahmann and Rahmann (1992) this functional model of neuronal gangliosides provides evidence that gangliosides:

> "are in involved in the transfer of information between cell surface and substances of the extracellular fluid...In light of these concepts, the phenomenon of short-term memory could be explained in terms of the activity-dependent (voltage-dependent) changes in configuration that occur at the outer membrane of hitherto unstable synapses, particularly in the region of the developing synaptic contact points" (p.261).

Rahmann and Rahmann (1992) conclude that:

> "the phenomenon of memory formation on the basis of molecular facilitation is rooted in the fact that the affected synaptic membrane regions in a neuronal network ...are modulated by physicochemical changes in the configuration of the varyingly polar Ca2+ -

> gangliosides complexes (possibly stimulation-specific in the sense of an 'electrical resonance of the ganglioside structure'). Moreover, only those signal impulses are transmitted efficiently that correspond to the original impulses...that occurred during the first memory storage event" (p.262).

This field of research led to the exploration of the function of neural circuitry which continues to date. With regard to visual memory storage, during the mapping of neuronal assemblies in the hippocampus and amygdala has provided structural correlates for the storage of visual data. They may be represented as reciprocal feedback mechanisms between the neuronal representation centers in the cortex and those of the hippocampus and amygdala. Intermediate recall, such as visualizing a person's face when an item belonging to him/her is touched, has been asociated with the amygdala because of its involvement in linking sensory channels. Additionally, long-lasting memories are believed to be achieved through reciprocity between the cortex and the amygdala. Long lasting memoris are thought to be stored diffusely over a wide region of these neuronal networks. In light of this, other more complex structures may exist which may account for the process of remembering. Holographic brain processes may be such structures and the VGM may be a mechanism operating within a three-dimensional domain which can exercise some control over the event of memory.

Biological Neural Networks

The existence of neural networks formed by the connection of synapse circuitry to form neuronal circuits within the brain is an accepted phenomena. Begley (1996) states:

> "Neurobiologists are still at the dawn of understanding exactly which kinds of experiences, or sensory input, wire the brain in which ways. They know a great deal about the circuit for vision...For other systems, researchers know what happens, but not-at the level of neurons and molecules-how. They nevertheless remain confident that cognitive abilities work much like sensory ones, for the brain is parsimonious in how it conducts its affairs: a mechanism that works fine for wiring vision is not likely to be abandoned when it comes to circuits for music." (p. 2)

Electrical impulse transmission occurs through the neurons and their synaptic connections. One group of neurons initiate the impulse from the external sensory input received. These impulses are carried through the axon terminals of the initiating neurons to a group of relay neurons and then finally, a group of interneurons. The interneurons conduct impulses back to the relay neurons (see Figure 19) and in doing so create an equalized impulse. These equalized impulses are then conducted back to the relay neurons creating a feedback loop.

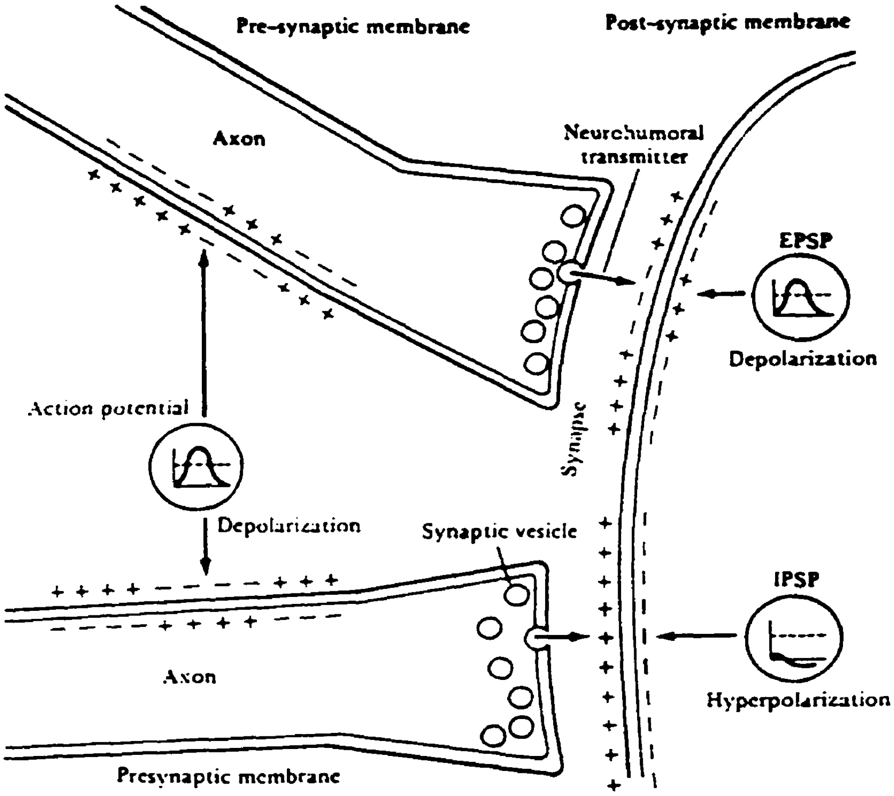


Figure 19. Brown's (1976) diagram for electorchemical events at a synaptic junction. Synaptic transmission is orthodronic, occurring in one direction only and is graded resulting in the synaptic region becoming a modulator which functions to make further transmission conditional upon the relation between facilitatory and inhibitory influences. When a nerve impulse arrives at the synapse a new form of transmission occurs. Described by Koelle (1965) as a four step process that is a four part sequence of events that occurs within a few milliseconds. Firstly there is a release of the transmitter substance stored within synaptic vesicles. The transmitter is discharged when depolarization of the axon terminal occurs, which then affects the dendrite of the next neuron. Secondly, there is a combination of the transmitter with the postsynaptic receptors an indicator of the postsynaptic potential. The transmitter diffuses across the gap to combine with receptors located on the surface of the postsynaptic membrane. When contact is made a localized non-propagated potential called the postsynaptic generator develops. It may be one of two types; the usual depolarization is due to Na+ ion disequilibrium and called excitatory postsynaptic potential (EPSP); the second involves hyperpolarization, an increase in membrane polarity and stability raising the threshold for an immediate subsequent depolarization and is called an inhibitory postsynaptic potential (IPSP). Third, there is the initiation of postsyaptic activity. If EPSP exceeds the threshold values for the neuron an action potential is initiated and conducted to the next synapse. An IPSP opposes or blocks excitatory potentials initiated by adjacent neurons. Many axon terminals converge on a single neuron and whether a postynaptic action potential will result depends on the summation of all the inputs at a given time. This summation can be spatial, in that the local potentials are initiated synchronously in the same region or they can be temporal, whereby local potentials arrive repetitively before the preceding ones decay. Four, the destruction or dissipation of the transmitter occurs. Enzymes destroy the transmitter substance once it has completed its influence on the postsynaptic membrane returning the membrane to its initial non transmitter state where transmitters are continuously but slowly released in amounts insufficient to cause postsynaptic excitation. [From Brown, 1976].

As a result reverse connections to the interneurons can occur. In this way many synaptic connections may be made in a single synapse triad that consists of an input neuron, an interneuron, and a relay neuron. When a number of these synapse triads are linked in a series or parallel fashion, for example as in the case of the retina, a complex system of neuronal circuitry results. The linking of neuronal circuits forms neural networks. The mode by which neuronal circuits may be linked depends upon type of synaptic contact and type of transmitter substance secreted on the cell membranes. Synaptic contact of the axon terminals can be made with the soma, the dendrites, or other axons of the receiving cell. Transmitter substances secreted by presynapses and the response mode of the postsynaptic membranes can be excitatory when stimulating the synapses or inhibitory when inhibiting synapses.

Simple neuronal circuitry systems include divergent, convergent, convergence-divergence, retroinhibition, lateral inhibition and positive feedback (see Figure 20).

Divergent circuitry (see Figure 20a) ocurrs with the relay of one neuron to several receiving neurons. For example, peripheral receptor cells adopt the mode of divergent circuitry. Their sensory fibers enter the spinal cord through dorsal roots branching out and supplying the nerves of the spinal column with impulses.

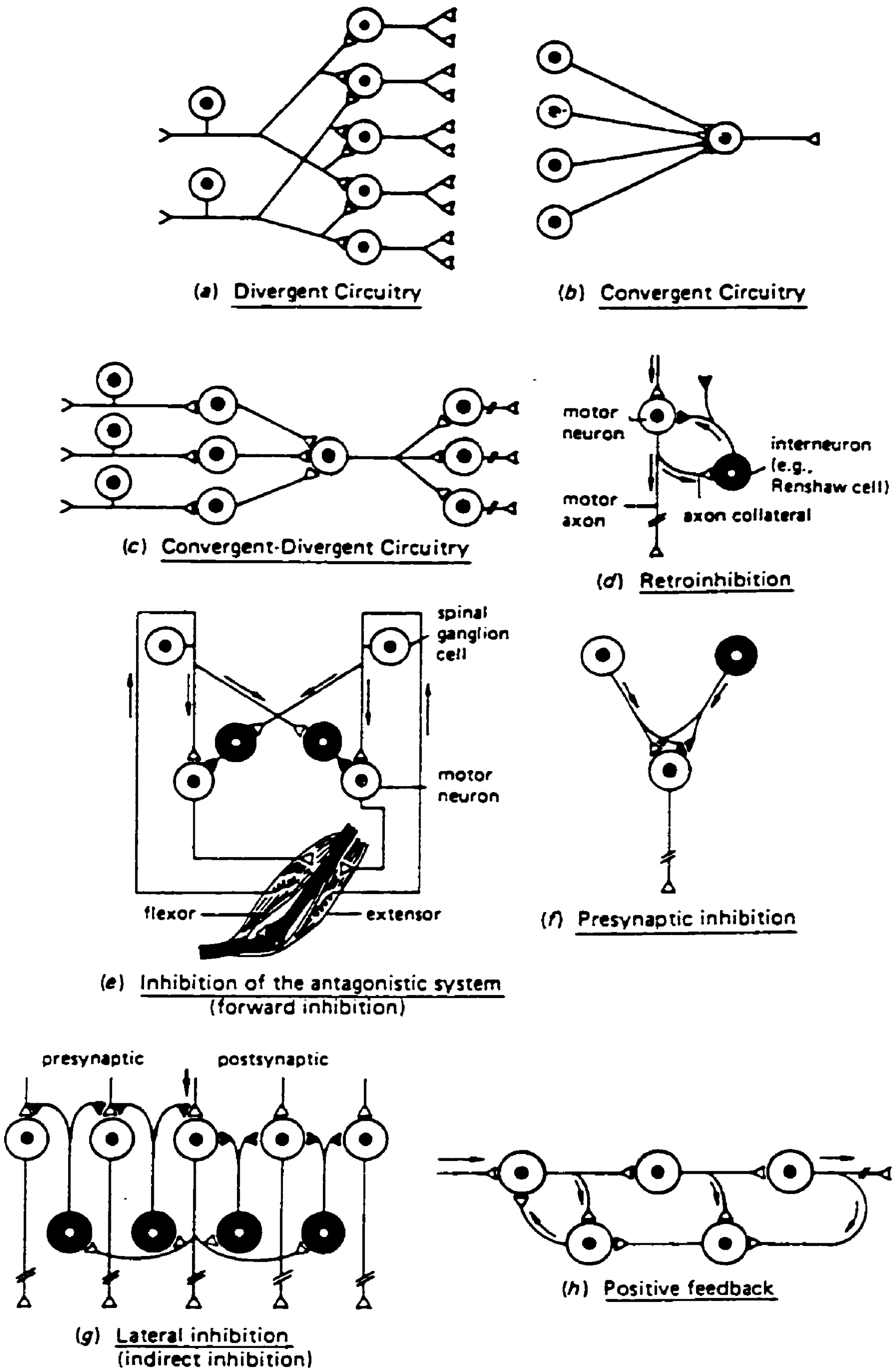


Figure 20. Rahmann and Rahmann's (1998) schematic illustrations providing an overview of simple neuronal circuitry systems. [From Rahmann and Rahmann, 1998.]

Convergent circuitry (see Figure 20b) occurs when the terminal branches of several neurons converge at one nerve cell, resulting in a spatial and temporal integration of impulses at the receiving nerve cell. According to Rahmann and Rahmann (1992) "in apes...the number of axon terminals believed to converge at one motorneuron in the spinal cord has been put at up to 19,000" (p.102).

Convergence-divergence circuitry (see Figure 20c) is a mode that describes a phenomena that occurs when both of the two previous modes are linked. Individual neurons receiving convergent input integrate the information and then distribute it divergently to several other receiving cells. The retina utilizes this mode of circuitry maintaining divergent connections with many receiving neurons in its photoreceptor cells and by receiving inward conducting convergent impulses from a multitude of photoreceptors.

There are two types of simple inhibitory neuronal assemblies in the CNS. One group is postsynaptic and the other group is presynaptic. In postsynaptic inhibition, the inhibitory synapse addresses the cell body of the neuron that is to be inhibited to prevent the depolarization of the postsynaptic membrane. To achieve this, two modes may be used, retroinhibition (see Figure 20d) and (see Figure 20e). Retroinhibition is a reverse or recurrent process that provides negative feedback. The excitatory neuron activates an inhibitory interneuron that reacts upon the excitatory neuron by reducing the discharge in the original neuron at the synapse. The Renshaw cell functions as an inhibitory motorneuron in the spinal cord. So, for example inhibition in the antagonistic system occurs when an inhibitory interneuron is stimulated directly by the afferent (or sending) neuron. This mode of circuitry is observed in the inhibition of extensor muscle neurons at the same time as the activation of flexor muscle neurons. In presynaptic inhibition (see Figure 20f), the inhibitory synapses of the inhibitor neuron addreses the presynaptic endings of excitatory cells to inhibit the secretion of the transmitter. In this way depolarization occurs at the presynaptic nerve endings and this results in weaker impulses that affect the filtering of signals and the intensification of signal contrast.

Lateral inhibition (see Figure 20g), determines whether the inhibiting neurons will react pre- or postsynaptically upon both the excited cell and upon adjacent cells with similar function that have either been weakly stimulated or not stimulated at all. The result is a very strong inhibition in the region surrounding the activated cells. This mode of circuitry is found in the retina where it functions to create or increase contrast.

Positive feedback (see Figure 20h) refers feedback from impulse neuronsto cells that have already been stimulated. This is a mode of circuitry that is still in dispute. Negative feedback assemblies in the CNS are accepted in the literature, so it may be assumed that positive feedback assemblies may also exist. It is proposed that once stimulated, these neuronal assemblies may sustain their activity over time and that short-term memory may exemplify this type of circuitry.

The study of neuronal assemblies, or biological neural networks has led researchers to examine how the human brain functions. The simulation and replication of the input, processing, and output of information in the human brain has been attempted on computer models. These experiments have taken the form of computer simulations, artificial intelligence (AI), and the engineering of artificial neural networks. Further discussion will follow the information on visual information processing in HM.

Visual Information Processing in Holographic Memory

The main computational event of visual information processing in holgraphic memory takes the form of a Fourier-like transform. Before these first holograms were constructed using optical filters, Gabor (1949), explained them as phase relationships which can be expressed mathematically as Fourier transforms. "Fourier transforms are special transforms of convolutional integral which have the property that the identical equation convolves and deconvolves" (Pribram, 1971, p.149). In other words the hologram behaves like a Fourier transform because information encoded at one stage can be decoded at a recurring stage.

According to holographic brain theory the image formed on the retina is transformed to a holographic or spectral domain. The input in this domain is distributed over groups of brain cells by the polarization of the synaptic junctions in the dendrite structures. During this process there is no localized image stored in the brain. Associations and correlations occur when other modules of the brain project onto these cells in the holographic domain. Memory, as part of consciousness, is a by product of the transformation back from the holographic to the image domain. The transformation occurs in response to the sensory experience of the stimulus and memory results by re-experiencing that initial sensation.

Temporal and spectral information are stored simultaneously in the brain which operates as a dissipative structure which self-organizes around the least action principle of minimizing uncertainty. For example, if a rock is observed to be thrown into a lake, a circular ripple will emanate from the point at which the rock entered the water. The eye will observe this and see the first series of concentric rings which are formed and the brain will store that experience as if in a freeze frame of a video tape of the experience. The brain limits the processing of the visual stimulus, capturing the moment from beginning to an arbitrary end rather than speculating endlessly about the infinite motion of the water as it continues to move in outward circles that become increasingly more difficult to observe with the passage of time. By mimimizing the extent of the event, the brain is free to be responsive to new inputs. In this way, the brain operates as a self-correcting device that in a computer would detect and intuitively close down open programs that are not in use to allow the operating system to maximize its efficiency in conducting the programs it is using.

Artificial Neural Networks and Parallel Processing

The artificial neural networks (ANN), developed on digital computers demonstrate the parallel processing ability of the human brain. Beeman (1998a) summarizes the development of ANN, which arose from the search for AI characterized by two generations: the First Generation pre-1955, and the Second Generation 1955-1970. Within the first generation, the philosophical basis of classical AI began as early as 1854 when George Boole proposed the hypothesis that human intellect could be represented by mathematical laws. In 1943, Warren McCulloch and Walter Pitts proposed a neural net model which "consisted of a network of synapses and neurons which behaved in a binary fashion" (p.2). In 1947, Arthur Samuel began working on a checkers playing program for IBM designed to have the capability to learn from its mistakes. In 1950 Alan Turing hypothesized that "machines may someday compete with men in all purely intellectual pursuits" (p.3). In 1950, Claude Shannon proposed the hypothesis that a computer could be programmed to play chess.

Within the second generation of AI development, Beeman reports that a hypothesis was proposed, in 1956, by John McCarthy and Marvin Minsky which stated that the search for AI should "proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it" (p.2). McCarthy proposed the term artificial intelligence. In 1957, Allan Newell, Herbert Simon and J.C. Shaw developed two AI programs, the Logic Theorist, and the General Problem Solver which proved mathematical theorems. Newell predicted that within a decade the world's chess champion would be a digital computer. Simon hypothesized that the human cognitive system is basically a serial device and proposed:

> "that when considered as a physical symbol system, the human brain can be fruitfully studied by a computer simulation of its processes. Information-processing psychology focuses on the problem of how strategies and constraints interact to produce effective behavior in tasks that require thinking" (p.4).

In 1961, Arthur Samuel was defeated by the AI checkers program he developed. In 1963, Joseph Weizenbaum introduced a natural-language program, Eliza that simulates a psychiatrist's work. In 1965, Edward Feigenbaum deveolped the first system to analyze spectrograph data called Dendral. In 1968, Bert Raphael wrote a Semantic Information Retreival that makes deductions from facts. In 1969, the first ambulatory robot, Shakey was built. In 1975, Edward Shortliffe introduced Mycin, a program which diagnoses bacterial infections based on symptoms. In 1976, Raj Readdy developed a speech understanding program, Hearsay. In 1979, the world's backgammon champion Louis Villa was defeated by BKG 9.8, a program developed by Hans Berlinger.

These early AI systems were characterized as imitating human reasoning, processing information sequentially, explicitly representing knowledge, using deductive reasoning, and having learning that occurs outside of the system. There are two problems which the early AI systems encountered. First, sequential computers of neural speeds could not approach human reaction time with the possible causes being incorrect algorithmic approaches or incorrect computational structures. A possible solution was to develop massive parallel computational structures. Second, the computer simulation of some fundamental higher mental functions remained unexplained, including memory storage and recall, recognition tasks for speech and vision, and common sense reasoning.

The neural network approach attempts to study human brain function as a dynamical system. Beeman(1998a) defines a dynamical system as having the following properties:

> "a dynamical system, starting from an initial condition, passes through a succession of states. If the initial state is associated with a certain description of the world, the successive states consist of transformations of this description, and may be considered as a processing of the initial information. An attractor is a state towards which the system may evolve, starting from certain initial conditions. The basin of attraction of an attractor ie precisely the set of initial conditions which give rise to an evolution terminating in that attractor. If an attractor consists of a unique state, it is called a fixed point or a stationary state" (p.6).

Developed out of the research on AI, ANN share a common origin and a common goal to formulate intelligence in

reductionist terms. In effect, to display this intelligence with machines and to create intelligent computers. Both approaches utilize qualitative information as input and output, have multidisciplinary applications, and function optimally when solving classification problems.

However the characteristics of AI and ANN systems greatly differ. Beeman describes the AI system as a symbolic approach which studies the human "mind, independently of the structure and functioning of its physical support" (p.6). AI imitates human reasoning, processes information sequentially, represents explicit knowledge, uses deductive reasoning and learning occurs outside of the system. ANN are robust dynamical systems, with the possibility to facilitate automated learning. They are concerned with the emmergent properties of the human brain, reaching their conclusions by applying rules to numerical values. All units work simultaneously.

> "While every rule in an AI system has a precise, pre-assigned meaning, it is common that several neurons in a dynamical model have no pre-defined meaning--they specialize, during the learning phase, in a manner which is often unexpected and difficult to understand for human observers. Dynamical systems utilize distributed representations....high level concepts can be defined as activation patterns over several neurons" (p.6).

Beeman characterizes an ANN system as imitating the structure and functioning of the human brain, having parallel information processing capabilities, representing implicit knowledge within its structure, applying inductive reasoning to the aquisition of knowledge, and mediating learning that occurs within the system.

With the introduction of ANN, in 1985, into the field of AI, the hypothesis that the human brain functions both as a sequential and a parallel processor of information became the focus of extensive research and development. This has resulted in the introduction of three dimensional interactive learning in virtual reality environments and a subsequent redefinition of haptic learning as it pertains to the human/computer interface. This aknowledgement of the brain as a parallel processor provides support to the holographic memory hypothesis, which functions primarily as a simultaneous, parallel encoding and retrieval memory mechanism.

Holographic Hypotheses

There are three emminent researchers who have been instrumental in the architecture of the holographic hypotheses. The holographic hypotheses proposed by quantum physicist David Bohm, neuropsychologist Karl, and biochemist Rupert Sheldrake are based upon a natural philosophy which surpasses physics alone while remaining true to established physical laws and principles. David Bohm (1994), proposed the concept of the undivided wholeness implicit in relativity, quantum physics and holograms. Karl Pribram (1994), proposed a concept of memory based on holographic principles, in which the brain processes holographic input to re-synthesize images in inner space. Rupert Sheldrake (in Smith, 1992) extended the holgraphic process to examine the effects of animating matter to provide an understanding of evolution and the nature of a living planet. According to Smith (1992), the holographic models they proposed provided hypotheses "to explain the connection between the anatomical brain with it's spiritual analogue and dimensions beyond time and space - the underlying frequency realm of the hologram" (p.4).

While space limitations prevent further discussion of Bohm's and Sheldrake's contributions to the conceptualization of holographic hypotheses, they are worth mentioning because in doing so it becomes apparent that the interest in holographic applications is multidisciplinary and that what one researcher proposes has not been developed without the impact of other branches of scientific inquiry.

Central to this study is the concept of the HM hypothesis proposed by Pribram. The idea proposed by Pribram, that information is stored holographically within the brain's cortex and subcortex in a dispersed manner has gained acceptance in the field of neurobiology. It is accepted that the repositories for memory are the locations in which the sensory impressions develop and that neuronal circuits exist beneath the cerebral cortex that provide feedback to the cortex as the memory is being formed. In this way Rahmann and Rahmann (1991), suggest that "the structural correlate to a memory storage event of visual impressions may well be represented by the reciprocal feedback mechanisms between the neuronal representation centers in the cortex and the neuronal assemblies of the hippocampus and amygdala" (p.266). Rahmann and Rahmann (1991), report a study conducted by Lashley, in 1950, in which animal researchers were able to determine that an isolated repository for memory could not be located within the nervous system of rats by conducting lesion-induced memory loss experiments. Lashley suggested that memory is stored in a distributed way among many structures and that the neurons responsible for storage could also be involved in retreival through a synergistic activity. Addressing the question as to whether memory is located in the brain in a localized or diffuse manner, recent research on visual perception has focussed upon the neuronal processing pathways for light stimulation.

The flow of a light stimulus from the retina via the optic nerve to the lateral geniculate bodies in the diencephalon is well documented. Visual impressions are initially processed in the occipital region of the cerebral cortex. However, a second pathway has been found in primates. It is presumed that the the flow of information detected in the visual impressions of monkeys is relevant to humans. In research discussed by Rahmann and Rahmann (1991), tests were performed on monkeys to test visual recall. Surgical procedures were used to determine that a visual perception formed in the subparietal cortex stimulates two parallel neuronal assemblies which constitute dual pathways. The first neuronal assembly is one which originates in the amygdaloid nucleus and the second is one that originates from the hippocampus. According to Rahmann and Rahmann (1992):

> "another projection pathway in the anterior pareital lobe is [also] responsible for processing spatial relationships with visual scenes. This other pathway for processing visual information, which is possible involved in memory formation of visual impressions (i.e., from the cerebral cortex into lower lying brain regions and, thus, into the underlying structures), can be identified... Apparently both regions are responsible for many kinds of cognitive learning, i.e., for the ability to recognize objects, to recall properties from memory that are not being perceived at the moment and to assign emotional significance to those properties. Apparently, however, neither of the regions represents the final location of those structures involved in perceiving and storing visual information, since projection pathways lead from here to the striate body and to the diecephalon (thalamus and hypothalamus) which, in turn closes the circle of information processing insofar as it sends neuronal pathways back to cerebral cortex." (see Figure 21).

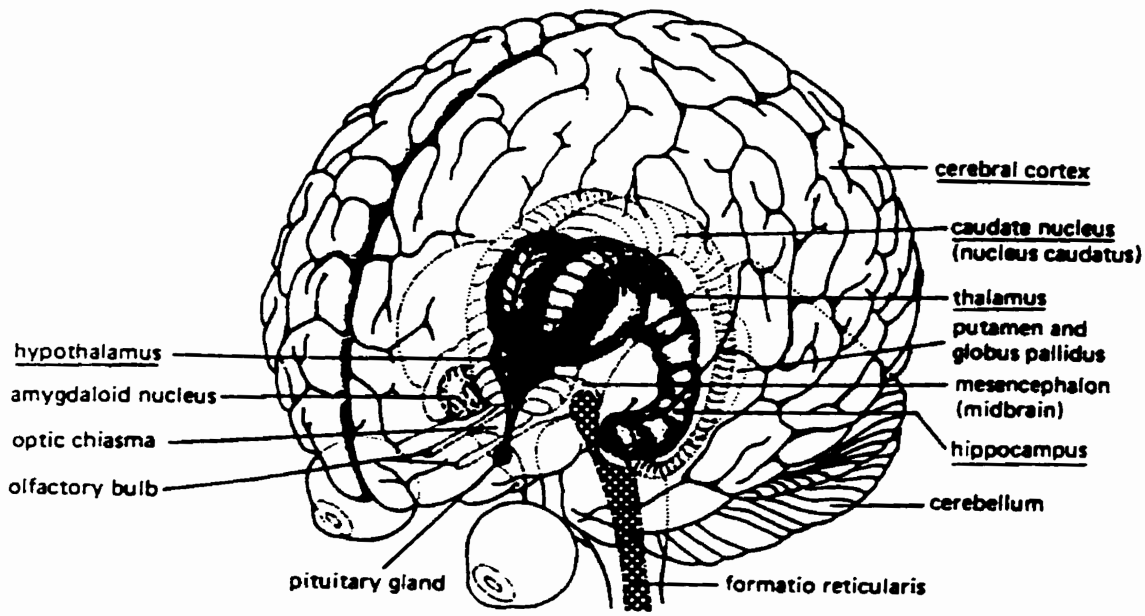


Figure 21. Rahmann and Rahmann's (1998) diagram of structures of human brain involved in memory. Structures believed to be involved in the depositing of memory content are underlined. [From Rahmann and Rahmann, 1998.]

Rahmann and Rahman (1991) conclude that there is evidence to support the idea that the storage of memory events occurs both in the visual cortex and in the hippocampus and amygdala. For this to happen the information must be distributed over the different parts of the brain. "Thus , individual memory inventories are stored not so much as the individual reference points of photograph, but as of a hologram, whereby it is possible to store and recall three-dimensional spatial scenes" (p.267).

According to Smith (1992):

"the hologram is a three-dimensional image made with a laser, a source of coherent light waves. To produce a hologram a single laser light is split into two seperate beams. The first beam is bounced off the object to be photographed; the second collides at the film plane with the reflected light of the first, producing an interference pattern, recorded on film. As soon as a light is shined on the developed film, a three dimensional image of the original object appears. Unlike normal photographs, every small fragment of a piece of holographic film contains all the information recorded in the whole. Holograms contain a fantastic capability for information storage. By changing the angle at which the laser beam strikes the film, or the beams wavelength, it is possible to record many different images on the same surface. A one inch square of film can store the same amount of information as contained in fifty large dictionaries" (p.3).

Evidence suggests that memory and perception may be based upon these holographic principles and that HM may account for the virtually unlimited potential of human brain function.

Holographic Memory Release Technique (HMR)

Support for the assumption that state-dependent memory can be re-coded to develop self-correcting abilities can be found in the work of Daily (1998a), a chiropodist who developed the Holographic Memory Release Technique (HMR):

> "HMR is an empowering approach to prevention and improvement that restores the necessary vital capacity to the mind/body continuum...Through very light and specific digital contacts, a piezoelectric effect is created within the crystalline connective tissue memory system for instantaneous memory reframing" (pp. 6-7).

While this approach pertains to the whole body as a microsystem and not specifically the memory capabilities of centers located within the brain, it has some relevant implications for the concept that somatic memory may be utilized in a restorative way which may lead to information release at a cellular level. In this technique, coherent waves of cellular resonance are generated in the connective tissue matrix to increase the ability to effectively process stored information.

According to Daily (1998b), state-dependent memory refers to the phenomena that:

> "memory is dependent upon and limited to the state in which it was acquired...Collateral communication pathways may exist between the spinal cord, the body/mind memory systems, and the cellular structures and the meningeal coverings of the brain and spinal cord (p.1).

The meningeal coverings of the spinal cord are seen as analagous to the multiple wave oscillator, and may generate a field in which each cell can locate its specific frequency to vibrate in resonance. "A sacral cranial rhythm may become a recurrent mestable solution wave running from the coccyx to the cranium... which may turn the dermatomal nervous system information into vibrational information for full body communication." (Daily, 1998b; p.3).

These findings may lend support to the proposal that wrongful or multiple encoding of stimuli can be corrected using the tactile sensory mode as the preferred mode of instruction for the study. In the study this took the form of haptic rehearsal strategies.

Somatic Recall Soft Tissue Memory and Soft Tissue Holography

Soft tissue memory and soft-tissue holography in somatic recall has been studied by Oschman and Oschman (1995a; 1995b). As a phenomenon, somatic recall does not fall within the parameters of the classical theories of how the human brain and CNS operate and as a result has been labeled an anomalie by conventional science.

Somatic recall. Reports from massage therapists that the phenomenon of touching someone to release and communicate memory traces are widespread. Oschmann and Oschmann (1995b), define somatic recall:

> "as the release during massage and other kinds of bodywork of repressed and often highly emotional memories. Often such 'flashbacks' are beneficial, leading to resolution of old trauma, pain or psychological attitudes...We take the view that the phenomenon is not only valid and therapeutic, but that it is an important clue that could help us answer unsolved questions about the mechanisms of learning, memory, consciousness, and whole-system communication" (p.1).

Somatic recall is explored by Oschmann and Oschmann (1995a), within the context of biophysics and cell biology to provide a scientific basis from which to consider this phenomenon:

> "Historically, physiological integration has not been a topic of great interest for biomedical research, which focuses on parts rather than wholes. Recent work of

biophysists around the world is now providing a context in which the experiences of massage therapists...can be validated scientifically....Biophysics is now progressing rapidly because of the whole-systems perpective. The search for fundamental units is replaced by the study of web relations between the various parts of the whole" (p.8).

The living matrix is capable of generating and conducting vibrations which may occur as mechanical waves or sounds, called phonons, electrical signals, magnetic fields, electromagnetic fields, heat, and light. According to Oschmann and Oschmann (1995a) "these forms of energy obey the established laws of physics [and] signals are produced and distributed throughout the body because of properties that are common to all of the components of the living matrix" (p.3). There are six properties which follow: (a) semiconduction- all components can conduct and process the vibrational information and can convert energy from one form to another, (b) piezoelectricity- all components are piezoelectric as waves of mechanical vibration pass through the living matrix to produce electric fields or waves of electricity move through the living matrix to produce mechanical vibrations, (c) crystallinity- a large portion of the living matrix contains molecules that are regularly arrayed in crystal-like lattices, including lipids in cell membranes, the collagen molecules in the connective tissue, the actin and myosin molecules of muscles and components of the cytosketeton, (d) coherency- these crystalline molecules produce giant coherent or laser-like oscillations, called Frohlich oscillations (Frohlich, 1988; Popp, Li, Gu, 1992; Popp, Ruth, Bahr, Bohm, Grab, Grolig, Rattenmeyer, Schmidt, and Wulle). These vibrations move rapidy throughout the living matrix and are radiated into the environment and occur at specific frequencies in the microwave and visible light continuum of the electromagnetic spectrum, (e) hydration- water, the dynamic component of the living matrix is polarized (dipoles). Each matrix protein has approximately 15,000 water molecules associated with it. These dipolar water molecules are organized to restrict their abilty to vibrate or rotate in different spatial planes, and, (f)continuity- the six properties just described are distributed throughout the organism.

Soft tissue memory. The continuum of communication creates a patterm of vibrations which are frequency modulated (FM). This process where vibratory signals are transmitted through the living matrix makes it possible for the organism to function as a whole. Additionally, the living matrix retains the memory of the influences exerted upon it because when the vibrations are transmitted through tissues, the tissues are altered by the signature of the stored information. It is in this way that memory is stored at a cellular level in the cytoskeleton or the nervous system of the cell and in the connective tissue creating soft tissue memory. It is proposed that the biophysical properties of the living matrix may explain some of the unexplained phenomenas associated with learning, memory, consciousness, and unity of structure and function.

The cytoskeleton contain microtubules which are rod like structures which give the cell its shape. Oschmann and Oschmann (1995a) cite Hammeroff's description:

> "Microtubules are made up of monomeric subunits known as tubulin. These subunits are polymerized into microtubules at specific sites known as 'microtubule organizing centers.' Microtubules are polymers (poly= many), formed when many identical units, called tubulin momomers (mono=one) join together...Each tubulin monomer is polarized, and has two differenr ways of fitting into the polymer. Additional proteins, called 'microtubule associated proteins' or MAP's, can attach to the microtubule. Information is stored by the orientation of the tubulin monomers and by the position of attachments MAP's. The result is a record of the conditions in the cell and in the environment at the time of microtubule assembly...The patterns of microtubules subunit form 'information strings'" (pp.4,5).

Oschmann and Oschmann (1995a) cite Jablonka who compares this information storage process in the microtubules to the computer information storage process of a word processor:

> "In the computer the information is stored on a magnetic medium in the form of a series of magnetic particles that can be oriented in either of two polarities, 'north-south' or 'south-north.' The disk drive can read these digital 'character strings' and reproduce the sequence of letters and words of our [the] manuscript. Similarly, information is stored as the orientation of tubulin monomers along microtubules. The information is in strings that can move along the microtubules. In nerves, very long microtubules and associated neurofilaments can function as devices that are known in computer terminology as string processors" (p.5).

Continuing the computer analogy, character strings which can be erased from the disk drive with a magnet that turns all of the magnetic particles to the same orientation, a similar process, of depolymerizing a microtubule so that it falls apart into its monomeric units, could erase information stored in soft tissue. For massage and other forms of bodywork, pressure, temperature change, magnetic fields, subcutaneous electrical impulse transmission and lasers can cause the microtubules to depolymerize.

Soft tissue holography. This complex way of storing information appealed to Karl Pribram. He developed his HMM on the assumption that memory is a distributed property of the nervous system and that memory is not erased by the removal of brain tissue both of which are the hallmarks of holography where information is stored through a distributive process and that retrieval of the entire image is possible from a single point of the hologram.

Gestalt Principles and Phenomenas

The Gestalt priciple of continuation of good figures and the phenomenas of multi-dimensional mindshift and the Cartesian axis orientation of visual perception provide additional structural support for the VGM theoretical framework. An overview of the Gestalt priciples and organization of visual processing will be provided to enable the VGM to be situated within this foundational memory model.

In the 1920's, a group of psychologists investigated how individual stimuli are grouped together during perception into wholes or Gestalts. Included in this group, which became known as the Gestalt psychologists were Kurt Koffka, Wolfgang Kohler, and Max Wertheimer. Their main concern in the area of visual perception was to identify the principles by which individual elements are combined into organized wholes which possess unique features that are not obvious when looking at their individual parts and to find the principles by which these gestalts are perceptually segregated from each other. Seven principles were established including proximity, similarity, common fate, good continuation, closure, area, and symmetry (see Figure 22). Research in this field consisted mainly of presenting subjects with visual stimuli patterns and asking them to describe what they saw. According to Spoehr and Lehmkhule (1982), these principles can be described as:

> "the principle of proximity...states that grouping of individual elements occurs on the basis of nearness or small distance...Thus spatial proximity forces grouping...and separation [of elements]...The principle of similarity [states that elements which are] physically similar form good perceptual groups...Thus...organization is produced by similarity of form...The principle of common fate [states that] if some of the elements [are] simultaneously shifted in position...the directionality of motion...gives them a common fate [which would cause the observer to group them together]...The principle of good continuation...states that the elements will be organized into wholes that yield few interruptions or changes in continuous lines...The principle of closure...states that our organization of elements tends to form them into simple, closed figures [called

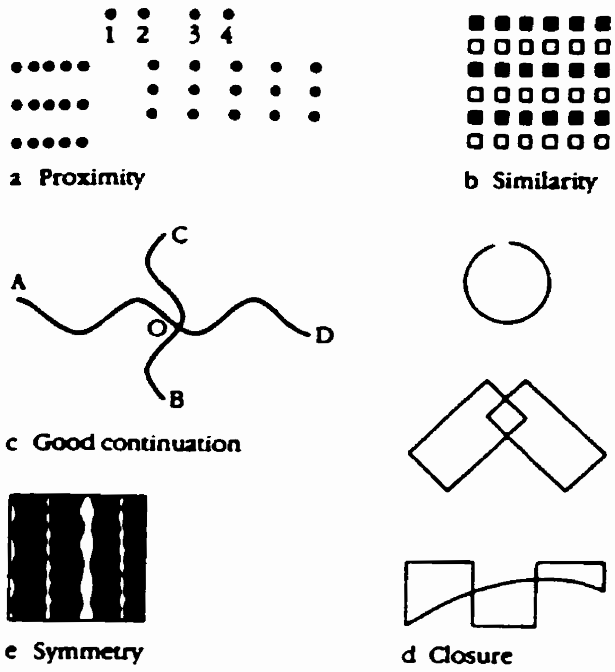


Figure 22 Spoehr and Lehmkuhle's (1981) illustrations of Gestalt principles of organization. [From Spoehr and Lehmkuhle, 1981.]

good figures], independent of their other continuation similarity, or proximity properties...closure works to counteract good continuation [and can] explain why we sometimes have difficulty performing embedded figure tasks ...The principle of area...states that the smaller of two overlapping figures is more likely to be viewed as the figure, and the larger as the ground. Area [is one factor that causes] one pattern to be segregated from another. [It has] a large influence on how the perceptual system segregates a figure from the background against which it is shown. A second principle of segregation, the principle of symmetry, states that the more symmetrical a figure is the more likely it is to be seen as a closed figure" (pp.65-67).

Spoehr and Lehmkuhle (1982) cited six studies which were conducted to validate the Gestault principles. First, in 1956, while conducting a study to determine the effects of proximity and similarity, "Hochberg and Silverstein found that vertical spacing had to be reduced quite a bit in order for proximity to counteract the similarity effect" (p. 68). They determined that "the weaker the similarity grouping, the less vertical contraction neccessary to counteract it" (p.68).

Second, in 1966 Beck explored the effects of the orientation and shape of the individual elements in forming similarity groupings. Beck found that "the repetition of individual elements makes subjects sensitive to certain properties that are not so important when only a few elements are present" (p.69).

Third, in 1970, Olson and Atteneave expanded upon Beck's research to show that similarity groupings are dependent not only upon the orientation of the elements but also "upon the slope of the component line segments [of the elements] relative to a horizontal-vertical reference system" (p.69). They "suggest that grouping depends on the subject's ability to generate an adequate internal description of the relationships between elements in the field" (p.70). Their results showed that elements which have only segments which are perpendicular to the horizontal and vertical axes are easiest to describe. Next, elements which have some of these segments in combination with others are more difficult to describe. Finally elements in which all Cartesian axis elements are identical with other distinguishing features are most difficult to describe. While these findings pertain to only one dimensional stimuli, there are implications which the idea of a Cartesian axis reliance brings to the VGM. Evidence that an orientation mechanism exists for unidimensional visual stimuli suggests that such a mechanism may operate in two or three dimensional visual stimuli and provides a basis from which to explore this phenomena from a multi-dimensional perspective.

Fourth, in 1953 Hochberg and McAlister studied the characteristics of good figures including, measures of planar simplicity such as number of line segments, angles, and points of intersection contained in drawings of three-dimensional cubes when viewed as both two and three-dimensional figures (see Figure 23). "The processing system organizes input into the simplest interpretation possible, and that the Gestalt principles ...are statements about which interpretations of a multielement stimulus are the simplest" (p.70). They found that when presented with a series of three drawings of a three-dimensional hexagonal cube from different angles of view, the subjects reported that version 1 in which the cubes containing 12 line segments were most simply described in three-dimensions (or good figures) were viewed as a two-dimensional hexagon containing interior line segments 60% of the time. In version 2, in cubes containing 13 line segments were perceived, 49% of the time, as two-dimensional. A perceptual flip occurred causing the cube to alternate back and forth between two and three-dimensional perspectives. In version 3, with cubes containing 16 line segments ("because many of the edges of the three-dimensional cube break into two segments at the interior intersection points in a two dimensional perspective" (p.70), subjects reported viewing the cube as a two-dimensional planar figure 1% of the time.

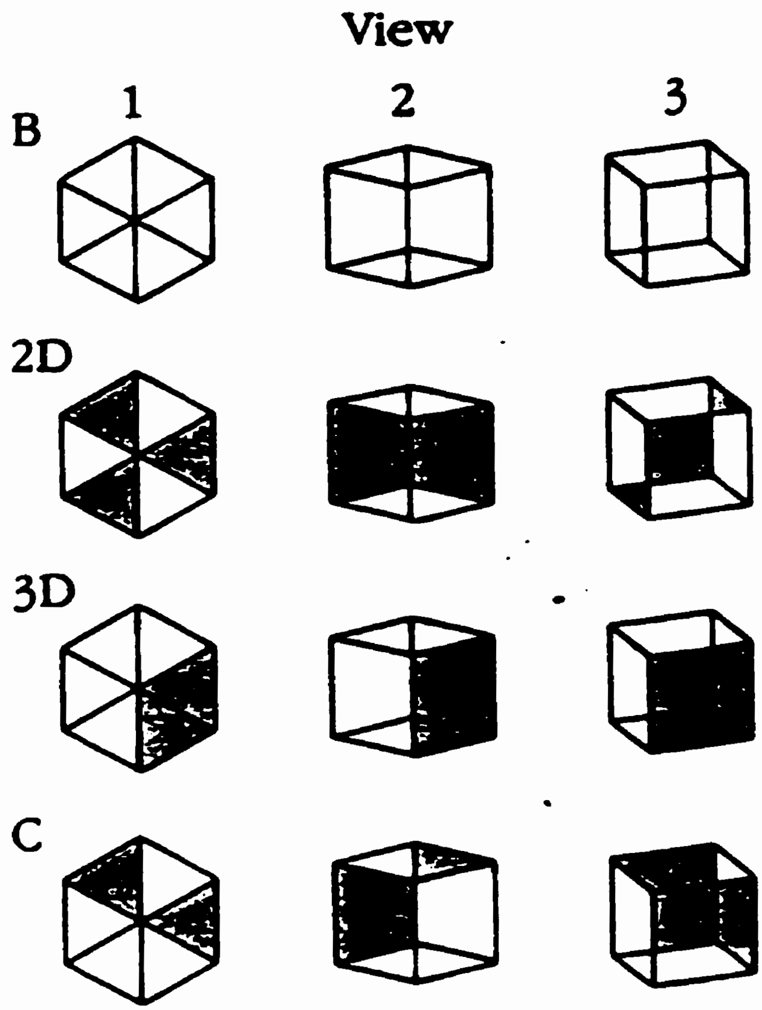


Figure 23. Spoehr and Lehmkuhle's (1982) interpretation of Hemenway and Palmer's (1978) effects of shading on figure simplicity. [From Spoehr and Lehmkuhle, 1981.]

Fifth, in 1978 Hemenway and Palmer studied the effects of shading on the organization of stimulus input for Hochenberg and McAlister's two and three-dimensional cube drawings. They found organization effects for dimensional perception when color cues were given by shading regions of the same surface, eliminating the ambiguity of whether two adjacent areas were part of the same surface. In this way, the simplest figures were perceived easily as three-dimensional.

Sixth, in 1974 Prytulak examined the principle of good continuation (which predicts how individual elements are organized when they are arranged in straight lines) to determine how continuation is affected by ambiguous stimuli "such as when two lines meet at an angle" (p.72). Prytulak predicted that the organization of the elements would be dependent upon the angle between two segments and upon the nature of the segments or elements surrounding them. The stimuli in this experiment were arrow dot patterns containing four dots in the shaft and two arms which radiated from a single shared dot at the end of the shaft. Subjects were presented with stimuli that had different angular arrangements of the arms and asked to indicate which arms were perceived as a continuation of the shaft. Results indicated that three stimulus characteristics rectilinearity, orientation, and enclosure had effects on the subjects' perception. The arm nearest to creating a 180 degree angle with the shaft or rectilinearity, was judged to be a better continuation. An arm whose orientation fell along the vertical or horizontal axis was grouped with the shaft more frequently than an arm which fell at an oblique angle. Finally the rectilinearity principle was found to exert a stronger influence when the two arms fell on both sides of the shaft, than when the arms fell on the same side (enclosure).

These studies, reviewed by Spoehr and Lehmkhule (1982), "show that the configuration of individual elements in a single stimulus lead to strong organizational effects that affect the interpretation or identification given to that stimulus" (p.72). The Gestalt psychologists were successful in identifying the principles which govern perceptual organization. This knowledge of the way in which figures are organized for visual analysis provided a basis for futher inquiry to determine the specific aspects of the stimuli which lead to these effects. As a result, a series of studies which attempted to account for the Gestalt principles within information theory followed.

Within information theory, it is believed that a stimulus containing a lot of information is easier to identify than one in which few visual cues are provided. According to Spoehr and Lehmkhule (1982), the identification of the aspects of the stimuli which convey information about it was first proposed by Attneave in 1954. This study provided an informational approach to studying the form of two figures, a black ink bottle sitting on a brown platform against a white background. The images were created by coloring squares within a 50-by-80 grid containing a total of 4000 squares to create the figures. Subjects attempted to recreate the pattern of the two figures by being given a blank grid and beginning in the lower left square working across the row to guess the correct color of each square. Random guessing could result in 4000 errors before identifying the colors of all the squares correctly. However, the feedback provided by identifying a pattern and generalizing that information to the next row reduced the mistakes made in guessing to approximately 20 errors in total. The feedback from each of the guesses provided information about the stimulus, such as the color of each square and the location and shape of the desk and the ink bottle, that was helpful in recreating the stimulus. The feedback provided information differentially because a guess which correctly identified the color of a square in the interior of one of the figures predicted from information already known did not provide new information. This feedback is redundant as it was surmised from the structure of the stimulus. The feedback about the squares along the edges of the figures provided more information because the edge contours are only predictable once the pattern is established. Therefore, the information about the structural organization of a figure is concentrated at the contours, in particular where there is a sudden change in direction of an edge. In this way, the elements which share the same information are grouped together perceptually to produce organized wholes. Within the context of "information theory the Gestalt principles of similarity, proximity, good continuation, and common fate...each refer to a situation of high redundancy" (p.74). In a restatement Hochberg and McAlister's concept of simplicity, Spoehr and Lehmkhule redefine the characteristics of good figures as

> " good figures are those that have both the fewest points of high informational content and the most redundancy. Thus the most perceptually simple interpretation of a line drawing is that in which there are fewest line segments and angles" (p.74).

The early Gestalt hypothesis of Continuation of Good Figures led to an investigation of the recognition processes involved in the organization of individual elements in pattern recognition. This research resulted in the notions of global and local processing. Global-to-local processing occurs when a subject, who is shown an array of objects, first organizes the elements into larger patterns and is aware of the emerging properties of the organized whole but not the details of the component elements. When asked to respond on the basis of the subparts, the subject breaks down the organized whole to analyze the components. The length of time required for this analysis depends upon the number of elements, with more time needed when there are many elements. Gestalt principles can describe which groupings will occur but how the subject performs this organization is still unknown. Spoehr and Lehmkhule (1982) cite studies conducted by Prinzmeal and Banks (1977), and Navon (1977) which confirm the global influence of organization on the recognition of component elements. Prinzmeal and Banks conducted two experiments the first using target characters in linear arrays and the second using distractor characters in nonlinear good configurations. The results of the former experiment indicated that subjects were quicker to report the target letter when it was presented next to the stimulus array rather than at its endpoint. The effect of good continuation to organize all the elements in the array into a single pattern obscured the component elements slowing down the process of detecting the target character. However when the target character was presented as a lone element, it was organized into a pattern by itself and identified immediately. In the second experiment, three arrangements of distractors and a target element were used to obtain simiar results with nonlinear good configurations. Predictably, the results confirmed the following expectations that: (a) when the target was physically separate from the distractor, the target stood out and was identified quickly because the distractor elements were grouped into a pattern excluding the target, (b) when the separate position was filled by the distractor and the target was part of the triangular arrangement the target was harder to identify because it is more difficult to detect among the distractors, (c) when the target and distractor elements formed a good figure, but with fewer elements in the arrangement, processing took more time than in (a) but less time than in (b).

This global-to-local processing phenomenon of object identification may operate to confound the spatial orientation ability of early years children who attempt to perform mental object rotation and other forms of manipulation to bring into view their perspective of object form with that adhered to within language and symbolic systems. It is this global influence that may contribute to the inability of early years students to gain control of the VGM. The treatment conditions to which the subjects will be exposed will attempt to facilitate the organization of the stimulus symbols presented in such a way as to improve recognition by assisting them to create patterns or groupings when presented with an array of objects through a haptically enhanced procedure to increase awareness of the emergent properties and an increased focus upon the details of the component elements or symbols presented in the array.

While not conclusive, the acceptance of biomolecular memory in the field of science, the redundancy of the brain to restore function after damage, the similarity of the Fourier-like transform to the receptor event of the visual pathways, the simulation of neural brain function by digital models of parallel processing theory, the hypothesis of the holographic domain and the non-localized function of memory storage, the ability to recode state-dependent memory using the HMR technique, soft tissue holography in somatic recall, and specified Gestalt phenomenas provide a framework within which it becomes possible to conceive that the VGM may exist and function holographically as a spatial orientation device. The plausibility of such a phenomenological mechanism exerting control over the position and orientation of symbols which must be learned to succeed in learning to read seems reasonable. A synthesis of memory models and research trends provides a basis for this inquiry which proposes a theoretical model, the VGM as a structural framework to examine and explain certain aspects of the phenomena of memory, observed in *pre-logical early years students.*

Virtual Gyrostatic Mechanism (VGM).

An approach which views spatial orientation as an important aspect of holographic memory is introduced. It provides a way to link haptic rehearsal strategies with the visual encoding of three-dimensional stimuli by accessing and gaining control of the hypothesized VGM believed to be involved in memory. This VGM may function to develop self-correcting tendencies which may improve literacy skill performance. A review of the literature indicates that spatial orientation is involved in the tranformation of visual input from the image to the holographic domain.

The VGM may act upon visual stimuli by orienting the perspective or point from which the brain sees it, akin to the functional properties of a *physical gyroscope*. Within the model of holographic memory, there is a place for such a mechanism to operate at a neurophysiological level. During the encoding or retrieval of neural holographic images, the gyroscopic mechanism may influence the lateral and vertical perpsectives of the image on a three-dimensional visual plane by facilitating a match between the stimulus and the stored image.

Experimental evidence supporting the orientation features of holographic principles is provided by De Valois, De Valois and Yund (1979). In animal studies with cats and monkeys, they found that the cortical cells of the subjects responded to the Fourier transform of the presented visual stimulus. In other words, that visual information processing occurs in the spectral or holographic domain and not in the image domain (by feature detection) as is popularly held to be the case in the conventional model of visual information processing. To obtain these results a series of experiments were conducted to explore the opposing views of the Euclidean-based geometric model of brain theory (conventional information processing) in which cortical cells act as non-linear edge detectors and the holographic mode of brain theory in which cortical cells act as linear spatial frequency filters.

The investigations conducted by De Valois and Yund (1979), Pribram (1993), Prideaux (1998), provided evidence that cortical cells respond to spectral information and that they act as spatial-frequency filters. This evidence suggests that spatial orientation is an important aspect of visual information processing. In holographic brain theory, this transformation of the visual image formed on the retina into the spectral domain (a Fourier-like transform) is the way in which information is encoded into HM where the information in this spectral domain is distributed over an area of the brain in a non-localized fashion. The importance of spatial orientation has been demonstrated in the sensitivity to higher spectral harmonics experiements. Indeed some rotational mechanism exists which operates to transform the visual stimuli into spectral frequency. It is proposed that a mechanism such as the VGM exists which can govern or control the ability to orient or perform these spectral transformations during the encoding of visual information. This proposed spatial orientation mechanismm responsible for the spectral transformation of visual input into Fourier-like transforms takes the form of a neural gyroscope, which operates in concert with the holographic principles of brain and mind.

Control of the VGM may explain how a symbol can be recognized regardless of spatial orientation or rotational position. Conversely, the lack of ability to exercise control over the VGM may explain why some students make repeated errors with letters and numerals by inverting, rotating, substituting, or transposing them. Further, access to controlling the VGM is believed to be a function of focussing attention through the use of haptic rehearsal enhancement strategies to bring learning into a conscious state. The research question asked in this study if gaining control of the VGM, through attention techniques involving haptic rehearsal, will have effects on literacy tasks for early years students.

The *physical gyroscope* is selected as the structural framework for this model of memory because of its unique spatial orientation governance capabilities. The classic image of a gyroscope is a fairly massive rotor suspended in light supporting rings called gimbals which have almost frictionless bearings that isolate the central rotor from outside torques. [see Figure 24]. The rigid frame gives its fast-moving center a stable formation without impeding its motion. This rapidly spinning mass is mounted on an apparatus that maintains the guroscope's plane of movement when rotated. At high speeds, the gyroscope exhibits extraordinary stability of balance and maintains the direction of the high speed rotation axis of its central rotor.

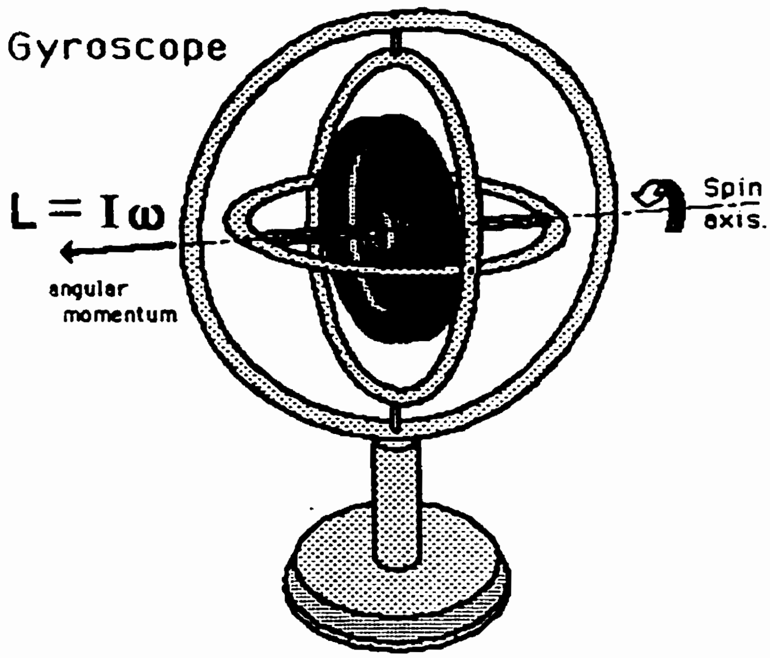


Figure 24. Turner's (1999) schematic illustration of a typical type of physical gyroscope. Shown are the rotor suspended inside three rings called gimbals. The rapidly spinning inner wheel will maintain its direction in space if the outside framework changes. [From Turner, 1999.]

The implication of the conservation of angular momemtum is that the angular momentum of the rotor maintains not only its magnitude, but also its direction in space in the absence of external torque. The classic type gyroscope finds application in gyro-compasses. When a gyroscope is tipped, the gimbals reorient to keep the spin axis of the rotor in the same direction because of the torque exerted by gravity on the gyroscope (see Figure 25).

The *neural gyroscope* is proposed because the spatial orientation and motion detection abilities of the physical gyroscope provide an appropriate model to hypothesize the existence of a VGM, operating as a spatial orientation device in the formation of visual HM.

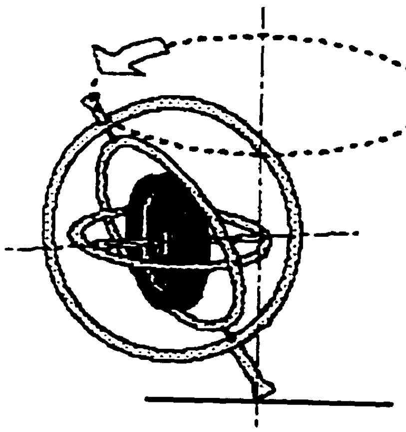


Figure 25. Turner's (1999) schematic illustration of typical gyroscopic precession. When the gyroscope is tipped, the gimbals will reorient to keep the spin axis of the rotor in the same direction. If released inthis orientation, the gyroscope will precess in the direction shown because of the torque exerted by gravity on the gyroscope. [From Turner, 1999.]

Holographic brain theory for visual information processing proposes that retinal cells respond not to the features (edges) of the visual stimuli but rather to the spectral transformation of that stimuli. For example a lowercase b when rotated horizontally 180 degrees appears as a lowercase d. When the lowercase b is rotated 180 degrees vertically it appears as a lowercase p and while undergoing the same 180 degree vertical rotation the lowercase d appears as a tailess lowercase q. When these four visual stimuli are presented together they appear to be visually different. (see Figure 26).

b	d
p	q

Figure 26. Visual Presentation of Lowercase Letters b,d,p,q Produced by Performing Vertical and Horizontal Rotation. When these four visual stimuli undergo the appropriate spectral transformation, it can be noted that the four orientations of the original lowercase letter b do not appear visually different from each other.

The neural gyroscope or VGM is proposed to be a phenomenological device or event which occurs synchronistically with the spectral transformation of the visual stimuli from the two-dimensional image domain to the three-dimensional holographic domain in memory. The neural gyroscope is selected as the theoretical model for the VGM because of the spatial orientation properties associated with the physical gyroscope.

CHAPTER 3

Methodology

Overview

This study was a controlled inquiry with hypothesized observable effects upon the two dependent variables, VGM control and literacy skill performance by the independent variable visual/haptic rehearsal enhancement which had three levels of treatment: (a) spatial-orientation identification, (b) manipulative re-orientation rotation, and (c) spatial matrix matching.

To provide a detailed examination and scientific understanding of the phenomenon under investigation four specific objectives were met. These included description, explanation, prediction, and control. The phenomenon of VGM control of visual input within the context of holographic memory was precisely described to identify and determine the degree to which antecendent conditions or variables may exist to produce it. Presenting the historical background, and a review of the literature to increase knowledge in this field of inquiry may result in the ability to predict and possibly control this phenomenological process. Predictions anticipating the VGM event prior to its occurence were based upon the combinations of variables believed by this researcher to be responsible for it. Knowledge of these antecedent conditions may make it possible to manipulate them to produce the desired effect of VGM control. In this sense control is achieved by gaining the knowledge of the causes of the VGM phenomenon and differs from the characteristics of the scientific approach control which refers to holding constant or eliminating the influence of extraneous variables in the experiment.

Research Method

An experimental research approach was used to observe the effects of systematically varying a single variable: haptic rehearsal strategies under controlled conditions.

The effect of haptically enhanced rehearsal strategies on gaining access to and developing control of the VGM was examined. How does haptic rehearsal influence the encoding of visual information during short-term and working memory? How does the retrieval of these haptically assisted encoded memories from long-term memory affect the performance on literacy skill performance tests? Systematically varying the methods of rehearsal, may demonstrate the influence of haptic rehearsal on gaining access to and developing control of the VGM. The disadvantages of the experimental method include the preclusion of the generalizability of results to any environment outside of the experimental setting, difficulty in designing an experiment in which subjects are totally controlled, manipulated and measured, and, the time consuming aspect of conducting the experiment.

The experimental research setting. The experimental research setting selected was a field experimentation. According to Christensen (1977) "The field experiment is an experimental research study that is conducted in a 'real life' setting. The experimenter actively manipulates variables and carefully controls for the influence of as many extraneous variables as the sistuation will permit" (p. 44). This study represented a field study because it was conducted in resource offices, natural settings for receiving testing and remedial instruction, during the course of the school day while subjects were involved in their daily activities. It also represented an experimental study because variable manipulation was present- type of haptic rehearsal strategy. There was randomization in the subject selection for assignment to groups in this study.

Research Design

The basic outline of this experimental study was as follows.

Description of Population and Subject Selection. Approximately 140 students aged 6,7, or 8 years attended early years classes in a large western Canadian urban school of approximately 450 students. Classroom teachers, resource teachers and a reading clinician were asked to put forward the names of students they believed met the criteria of either of two groups. Group #1 consisted of students who demonstrated letter and numeral reversals, inversions, transpositions or substitutions in their written work, who were experiencing early reading learning difficulties and who had intact visual hardware, with or without corrective prescription lenses, were not color blind or diagnosed epileptics. Group #2 consisted of students who did not demonstrate letter and numeral reversals, inversions, transpositions or substitutions in their written work, who had developed strong early reading abilities and who had intact visual hardware, with or without corrective prescription lenses, were not color blind or diagnosed epileptics.

Sample Selection Procedures. Ten names for each of the two experimental groups were randomly selected from the stratefied sample of all students identified by classrom teachers, resource teachers and the reading clincian as having met the criteria for one of the two groups. Names and recommended group assignment of all students considered eligible for participation in the study were written on slips of paper and put in a box. The slips of paper were drawn successively until ten subjects for each experimental group were selected. Letters were sent home to the parents of these 20 students requesting their informed consent for the voluntary participation of their child in the study. When consent was denied for any of the subjects, additional names were selected randomly from those nominated by the classroom teachers, resource teachers and the reading clinician until there were ten subjects per group.

<u>Design</u>. A mixed design was used to evaluate the results of the between-subjects variable (VGM control) and the within-subjects variable (literacy skills performance). A simultaneous-treatment design was used with multiple-baselines. Tests of Pre-Literacy Skills were administered to determine assignment of subjects to groups. This test measured pre-literacy skill performance and pre-logical thinking ability. First, pre-literacy skill performance was obtained through a battery of informal tests including verbally spelling the subject's name backwards, upside down recognition of images, reading mirror images, and logical reasoning (using the 1976 Psycan Missing Elements subtest of The KeyMath Diagnostic Arithmetic Test-R). Second, measures of pre-logical thinking ablility were assessed using selected tasks from "The Development of a Piagetian Paper-and-Pencil Test for Assessing Concrete-Operational Reasoning", and through a test of conservation skills, both taken from Sund's, R. (1976) book "Piaget for Educators".

<u>Assignment to Groups</u>. Assignment to Group #1- Students Not in Control of VGM, was determined by students meeting the following two criteria. Criteria one, on measure one, students who demonstrated pre-literacy skill errors on some form of either letter, numeral and shape inversions, reversals, transpositions and/or substitutions, and logical errors. The second criteria was that students demonstrated only concrete operational reasoning ability by obtained test scores.

Assignment to Group #2- Students in Control of VGM, was determined by students meeting the following two criteria. The first criteria was that students failed to demonstrate pre-literacy skill errors in any form of letter, numeral, and shape inversions, reversals, transpositions and/or substitutions or logical errors. The second criteria was, on measure two- Pre-logical Thinking Ability, that students demonstrated concrete-operational and/or logical reasoning by obtained test scores.

Experimental Procedures. After assignment to groups, subjects in both experimental groups were administered Form A of a Test of Literacy Skills compiled by the researcher including letter and numeral recognition, printing the upper and lowercase alphabet, sight word recognition (using the Bader Word Recogniton Grade Placement Test; Bader., L., 1993), oral reading comprehension (using Form A -Alberta Diagnostic Reading Test from the Alberta Diagnostic Reading Program-R; Alberta Ministry of Edcation, 1990), numeration knowledge and mental computation (using the Numeration and Mental Computation subtests of the KeyMath Diagnostic Arithmetic Test-R; Psycan, 1981), puzzle making, a stimulus writing sample and a journal entry.

All subjects were taught to gain control of the VGM so they would develop self-correcting tendencies using a haptic rehearsal strategy. This procedure utilized concrete symbols (stuffed toys, wooden letters and numerals) as stimuli for input and rehearsal in short-term and working memory called. This strategy was called, visual/haptic rehearsal enhancement (VHRE), in a single three treatment condition with three levels: (a) stuffed toys -tiger, cow and raccoon; (b) wooden numerals- straight 1,4,7, curved- 2,3,5 and closed- 6,8,9; and (c) wooden letters- open/short- n,u,v,m,w, closed- b,d,p,g,q, and open h,y,j,f,t.

Each subject received each treatment condition in all of the possible orders ABC,BCA,CAB,BAC,CBA,ACB to control for order of treatment effects. Checklists and anecdotal observations of student perfomance were recorded.

A post-test, (Form B an alternate form of the pre-test given for literacy skills assessment) of the Literacy Skills Test compiled by this researcher was administered to all subjects. This post-test included: a sight word recognition test developed from Dolch Sight Word Vocabulary and commercially graded novels designed to be an alternate form of the Bader Word Recognition Grade Placement Test, oral reading comprehension (using Form B- Alberta Diagnostic Reading Test), numeration and mental computation (using a parallel form developed by the researcher of the Numeration and Mental Computation subtests of the KeyMath Diagnostic Artithmetic Test, and puzzle making using a second, similar but different puzzle as is used in the pre-test.

Data Processing and Analysis (Statistical).

Test Results were compared between the pre- and post-assessments. Averages, means and medians were calculated. Statistical analyses included: a) The Wilcoxon Matched-Pairs Signed-Ranks Test ($p \leq .05$) for pre-test to post-test comparison for each group(ie. Group #1 pre-test to Group #1 post-test and Group #2 pre-test to Group #2 post-test). The tests were two-tailed and b) The Kilmorogov-Smirnov Two-Sample Test ($p \leq .05$) for group to group comparisons (ie. Group #1 pre-test to Group #2 pre-test and Group #1 post-test to Group #2 post-test. The tests were two-tailed.

Data was gathered, for this twenty subject study over a period of 11 school days which were specified in the following four steps: a) Day 1/Step #1- Pre-Literacy Skills Screening Test to assign to experimental groups; #1- Students Not in Control of VGM, and #2- Students in Control of VGM (aproximately 15 minutes to administer). Twenty subjects were assessed; b) Days 2 and 3/Step #2- Form A Pre-Test of Literacy Skills (approximately 30 minutes to administer). Approximately ten subjects were tested per day for a total of two days; c) Days 4,5,6, 8,9,10/Step #3- Treatment Conditions 1,2,3. Subjects were randomly assigned to four groups each with five subjects, Groups a, b, c, and d. Order of treatment condition were assigned so that all possible combinations were delivered ABC,BCA,CAB,ACB,BAC,CBA to each subject over a period of three, fifteen minute sessions over three consecutive days, followed immediately on the fourth day by the post-test; d) Days 7 and 11/Step #4- Form B Post-test of Literacy Skills.

Day Four

Group (a) received treatment conditions ABC, BCA.

Group (b) received treatment conditions BCA, CAB.

Day Five

Group (a) received treatment conditions CAB, ACB.

Group (b) received treatment conditions ACB, BAC.

Day Six

Group (a) received treatment conditions BAC, CAB

Group (b) received treatment conditions CBA, ABC.

Day Seven

Group (a) were administered the Form B Post-test.

Group (b) were administered the Form B Post-test.

Day Eight

Group (c) received treatment conditions CAB, ACB.

Group (d) received treatment conditions ACB, BAC.

Day Nine

Group (c) received treatment conditions BAC, CBA.

Group (d) received treatment conditions CBA, ABC.

Day Ten

Group (c) received treatment conditions ABC, CBA.

Group (d) received treatment conditions BCA, CAB.

Day Eleven

Group (c) were administered the Form B Post-test.

Group (d) were administered the Form B Post-test.

Variables.

Independent variable- One independent variable with three levels of variation; spatial-orientation identification, manipulative re-orientation rotation, and spatial matrix matching. The antecedent condition or variation and the control of this variation was rehearsal with concrete haptic enhancers; stuffed toys, wooden numerals and wooden letters. The independent variable was defined by specifying the events used to generate it and by formulating a new conceptual variable called haptic rehearsal strategy.

Dependent variable- One dependent variable, literacy skill performance with three levels- ability to gain control of the VGM to spatially orient objects, ability to recall visual information holographically and numeracy and literacy skills performance.

Limitations.

History, refers to external events, other than the independent variable, which happen between the pre- and post-test measurement of the independent variable (Christensen, 1977). To control for history, the time lapse between the pre and post-test measurement of the three, individual multiple-treatment variables was limited to a period of time that did not exceed five consecutive instructional school days for subgroups (a) and (b) and a period of time that did not exceed nine consecutive instructional school days for subgroups (c) and (d). The length of the entire study including screening for assignment to treatment groups , Group #1 a,d Group #2, pre and post-test measurement of the dependent variable did not exceed eleven instructional school days.

Maturation, refers to biological and physiological changes in the internal conditions of the subject (age, learning, fatigue, boredom, and hunger) which take place with the passage of time (Christensen, 1997). For the potential rival influence of maturation, a control of limiting the length of the study to eleven instructional school days was used.

Instrumentation, refers to changes that occur over time during the process of the measurement of the dependent variable due to the tester gaining skill over time and can result in the collection of more reliable and valid data as additional tests are give (Christensen, 1977). To control for instrumentation effect a typed script was used for verbal directi~~ons and data collection~~ forms were used to record behavioral responses.

Statistical regression, refers to the fact that extreme scores in a particular distribution will tend to move, or regress toward the mean of the distribution as a function of repeated testing (Christensen, 1977). As this study utilized 2 groups with extreme criterion scores, statistical regression was controlled by limiting the repeated testing to a single pre- and single post-test of alternate forms.

Selection, refers to a bias created when subjects differentially are assigned to treatment groups (Christensen, 1977). There was no control for selection, as subjects although randomly assigned within treatment groups, were differentially assigned to either of the two groups based on specified criteria for group inclusion.

Mortality, refers to subject loss from the various comparison groups that may produce differences in the group that can not be attributed to the experimental treatment (Christensen, 1977). To control for subject loss, the study was conducted during the winter mid-term period, when there are fewer school transfers and school closures for statuatory holidays.

Subject bias, refers to the attitudes and predispositions that a subject brings to the testing situation that can alter the subject's behavior in the experimental task (Christensen, 1977). Included are subject motives and, personality influence. Subject motives can result in *good subject* effects, where subjects attempt to do their best to succeed in the testing situation while attempting to figure out the true purpose of the experiment, *evaluative apprehension*, where subjects experience some stress or anxiety about receiving good test scores, *faithful subject*, where subjects attempt to do their best job, by following directions to the letter and do not act on any of their own hunches about how to respond if that response differs from what they believe to be the expected response, and, *uncooperative and hostile subject*, where the subject are untrusting and provide false responses because of their negative attitudes (Christensen, 1977). Techniques used for controlling for this type of bias included; (a) the provision of a clear statement of the purpose of the experiment at the subjects' comprehension level read aloud by the tester prior to the initial pre-test, (b) the use of a games format for testing to reduce fears about formal testing, and, (c) the use of pre-selected verbal reinforcers. While non-verbal gestures(Jones and Cooper, 1971; Felton, 1971; and Rosenthal, 1969) and paralinguistic cues (Adair, 1973) have been shown to mediate bias effects by communicating expectancy, this form of verbal reinforcement is one that early years students are familiar with in their learning environments and was assumed not to be a confounding variable as no novelty in this form of praise and encouragement should exist. In fact, not providing verbal feedback or encouraging smiles would create a more artificial setting than the subjects are accustomed to and to use blatant hostility toward receiving instruction a criterion which would disqualify a student from the study population. Finally, subject effects were controlled by selecting a maximum of seven students per classroom, to reduce the chances that subjects would talk together about their participation. In addition, the classroom teachers were told the purpose of the study, and were instructed to not ask the children about the study while it was in progress. They were provided with a list of acceptable responses to use when responding to questions their students asked about the study, and told to redirect their child's questions to the researcher. Finally, the teachers were asked to make a conscious effort to avoid correcting the letter and numeral errors the subjects made in their classroom work during the study.

Experimenter bias, refers to the inability of the experimenter to illicit identical data from subjects based on consistent impartial observation and non-biased recording, potentially biasing the results of the experiment (Christiensen, 1977). The experimenter is at risk for creating two types of bias in the obtained results. These include bias that arises from the attributes of the experimenter affecting the role of the subject which can vary as a function of the social interaction with the experimenter and bias that results from the expectancy of the experimenter such as motives for conducting the experiment(the conferral of a degree if significant results are achieved), expectations to confirm hypotheses (unintentionally influencing the recording of data in support of research questions). To control for the experimenter bias, data was recorded in a straightforward manner on observation charts during testing and treatment, and brief anecdotal supplements were recorded immediately after the student leaft the testing room and post-tests were administered by two research assistants.

Sequencing and carry-over effects, refer to the influence on the independent variable that multiple treatment conditions create when subjects are exposed to a sequence of treatment conditions where participation in one condition affects the response the subject makes in a subsequent treatment condition (Christensen, 1977). To control for this bias, the order in which the treatment conditions was presented was varied (ABC, BCA, CAB, BAC, CBA, ACB), so that each subject received each treatment condition in all of the possible orders an equal number of times. To further vary the presentation of the treatment conditions, there was a staggered starting point for each of the testing sub-groups, group (a), group (b), group (c) and group (d).

Population validity refers to the ability to generalize from the sample on which the study was conducted to the larger population (Christenesen, 1977). In this study, generalizations beyond the experimental population to a larger population of early years pre-logical students cannot be made with confidence because the population from which the subjects were selected may not be representative of the entire population and the selection was not random.

Ecological validity refers to the ability to generalize the results from the environmental conditions under which the study was conducted (one-to-one tutorial, withdrawal) to other environmental conditions (such as home and the classroom) (Christensen, 1977). The physical setting for the experimental condition was one of two resource offices. The time of day that the treatment was administered included both a.m. and p.m., and the experimenter was a certified teacher. As the format was individualized tutorial, the treatment effects may be subject to environmental effects and so the generalization of the results back to the classroom for learning formats in small and large group or any other than the one-to-one tutorial is not valid.

Multiple-treatment interference refers to the effect that participation in one treatment condition has upon participation in a second treatment condition (Christensen, 1977). This sequencing or carry-over effect impedes direct generalization of the study because the validity of the results is restricted to the order in which the conditions were administered. To separate the effect of a particular order of conditions from the effect of the treatment conditions, the four subgroups groups (5 subjects each) received their treatment in the following different orders-Subgroup (a) ABC, BCA, CBA, CAB, BAC, ACB. Subgroup (b) BCA, CBA, CAB, BAC, ACB, ABC. Subgroup (c) CBA, CAB, BAC, ACB, ABC, BCA. Subgroup (d) CAB, BAC, ACB, ABC, BCA, CBA.

The Hawthorne effect refers to the fact that subjects performances in an experiment are affected by knowledge that they are in an experiment (Christensen, 1977). Shifts in experimental behavior such as higher degrees of compliance and diligence may occur that will affect performance on the dependent variable so that experimental results cannot be accounted for by just the treatment effect.

The novelty effect refers to a phenomenon where the treatment condition involves something new or unusual producing an effect which, once the newness of the activity wears off, diminishes.

The pre-testing effect refers to the influence that administering the pre-test may have had on the experimental treatment effect (Christensen, 1977).

Other extraneous variables, refers to any variable that could possible affect the experiment and can include physical variables such as setting, light, sound, apparatus, and materials. The adequacy of these variables was controlled for by using resource rooms settings which were conducive to individualized instruction.

The most striking practical implications of this study are the time lost to classroom instuction and the amount of direct adult supervision required to conduct the intervention. Intense one-to-one instruction in a hands-on environment is needed to facilitate the haptic rehearsal through ongoing corrective physical and verbal feedback. This requires the instructional support of a teacher, teacher aide, volunteer or clinician. Given the limited human resources available at the classroom level, such an intervention is not realistic. A clinical environment such as a diagnostic learning center, attended outside of the regular school day may be a more suitable environment in which to deliver the intervention.

Seven critical variables not considered in the research design include: the constraints of time in selecting subjects who met all of the eligibility criteria for each of the experimental and control groups, the sensitivity of the instruments selected to assess reading skill performance on the pre and post-test subtests, the homogeneous streaming of grade two students into classroom groupings, the dual track French/English school site, experimenter error for the order of treatment conditions, subject boredom, fatigue and hunger, the delay in startdate for the study which resulted in the study coinciding with the Festival du Voyager Week during days eight through eleven, the inclusion of two ADHD students, one on and the other off medication, and, novelty effects for post-test administration by the two research assistants.

Research hypotheses (variables).

The single independent variable will be shown to have statistically significant effects on the single dependent variable with alpha set at $p \leq .05$. The independent variable, visual/haptic rehearsal enhacement with three levels; spatial-orientation identification, manipulative re-orientation rotation, and spatial matrix matching (with stuffed toys, wooden numerals, wooden letters) will improve the performance on the single dependent variable, literacy skill performance with three levels; ability to gain control of the VGM to spatially orient objects, ability to recall visual information holographically, and improved numerary and literary skills.

Null hypotheses. There is no statistically significant difference between pre- and post-test scores of subjects. The independent variable has no effect on the dependent variable.

Pilot Study.

After passing ethics review a trial study was conducted and involved three volunteer subjects of friends and family who met the population descriptors. Test instrumentation and procedures were practised, evaluated and revised.

Ethical considerations.

In conducting this experiment which involved human subjects the American Psychological Association's (1973) code of ethics which consists of 10 principles was adopted. These principles included; (a) the investigator's moral responsibility to evaluate whether the study violates any of the principles and if it does to seek ethical advice, (b) the investigator maintains responsibility for insuring ethical conduct throughout the research, multiplying the responsibility when co-principal investigators are used, (c) the investigator has the ethical responsibility of informing subjects of all aspects of the study that might influence their willingness to participate and to answer any other questions regarding the research project and to obtain informed consent from the subjects, (e) to respect the individual's right to decline to participate in the study, or to discontinue at any time (freedom from coercion), (f) the establishment of a clear and fair agreement between the investigator and the subject that clarifies the responsibilities of each and the obligation for the investigator to honor all promises made in that agreement and to protect the subject from any physical or mental harm or discomfort, (g) to follow up after data collection to provide subjects with clarification of the nature of the study and to remove misconceptions that may have formed, (h) the investigator accepts the responsibility to detect and immediately remove any undesirable consequences which procedures may have created for the subjects and is required to do long-term follow-up to assure that harmful after effects have not persisted, (i) to plan and maintain confidentiality of the data collected on the subjects (no disclosure without consent of the subject), and, (j) to explain these plans and to explain the limits of confidentiality in law as part of the procedure for obtaining informed consent.

Instrumentation.

To acertain how information is encoded requires empirical evidence indicating how the information is represented in memory. The purpose was to facilitate the holographic encoding of visual stimuli. The following protocols were followed: a) The subjects were asked to look at a series of photographs representing stuffed toys, wooden numerals and wooden letters. Each photograph showed a stimulus object from the following orientations; infront, behind, sideways turned right, sideways turned left, top and bottom; b) each subject was asked to point to the photograph that identified the stimulus object in each of the positions; c) the photograph was removed and a corresponding concrete stimulus object was handed to the subject. The researcher sat beside the subject and asked the subject to demonstrate the orientation positions described above by holding and repositioning the stimulus object. If errors were made in the orientation of the object to the correct position in the first trial, the researcher began a rehearsal trial, and physically assisted the subject in a hand over hand fashion to rotate and reposition the stimulus to the correct orientation specified. This rehearsal trial was repeated until, the subject's view matched the orientation specified or until two rehearsal trials were completed; d) the photographs of the objects were shown again after the haptic rehearsal was completed, and the subject was then asked to match the position of the concrete stimulus with the orientation depicted in each of the photographs; and e) subjects were given the following neutral verbal reinforcement when they performed tasks, "Thanks for doing that" and "O.K." regardless of whether they performed the task correctly or incorrectly. During rehearsal trials, a failure to perform the task correctly was given the verbal reinforcement, "Good effort, let's try it again", followed by the physical assist to reorient the stimulus symbol.

Treatment : Trials #1, #2, #3 stuffed toy animals phase #1- spatial orientation identification. The researcher showed the subject an 3 x 2 array of photographs of the tiger stimulus. Each photograph was arranged in a specified position and numbered as follows: 1) frontal; 2) behind; 3) sideways turned right; 4) sideways turned left; 5) top; and 6) bottom. The subject was asked to identify the object in photo #1. Then the student was asked to describe what position they saw the identified objects is in, in each of the photos 1,2,3,4,5, and 6. Correct reponses for this task included; a tiger, infront, the front, the back or from behind, sideways turned right, sideways turned left, the top or on top, and the bottom or underneath or from below. When a partially correct response was given, the researcher verbally reinforced the subject and then prompted the subject to clarify his/her response. The following prompts were used for partially correct answers:

1.) Object Identification

Researcher: "Look at photo #1. Can you tell me what the object in this photo is called?"

Subject: "A stuffed toy...an animal."

Researcher: "O.K. Can you tell me what type of stuffed toy...animal it is?"

Subject: "A tiger."

Researcher: "O.K."

2.) Frontal Position

Researcher: "Look at photo #1. What position do you see the tiger in?" (If subject incorrectly identifies object in photo #1 then use the term the subject has designated as a name for the object for the remainder of this trial).

Subject: "The face."

Researcher: "O.K.. Where do you have to be to see the face?"

Subject: "Across from it."

Researcher: "O.K. So what position does the tiger have to be in for you to be across from it?"

Subject: "Infront."

Researcher: "O.K."

3) Behind Position

Subject: "The bum...backside...butt."

Researcher: "O.K. Where do you have to be to see the bum...backside..butt?"

Subject: "Across from it."

Researcher: "O.K. So which direction do you have to be across from it?

Subject: "Behind."

Researcher: "O.K."

3) Sideways Turned Right Position

Subject: "The side."

Researcher : "O.K. Can you tell me which side, right or left?"

Subject: "Right."

Researcher: "O.K."

4) Sideways Turned Left Position

Subject: "The side."

Researcher: "O.K. Can you tell me which side, right or left?"

Subject: "Left."

Researcher: "O.K."

5) Top Position

Subject: "The head."

Researcher: "O.K. To see the head from that view where do you have to be looking from?"

Subject: "On top."

Researcher: "O.K."

6) Bottom Position

Subject: "The belly."

Researcher: "O.K. To see the belly from that view where do you have to be looking from?"

Subject: "Below."

Researcher: "O.K."

Phase #2- Manipulative Re-orientation Rotation

The photograph array was removed and the corresponding concrete stimulus of a tiger was passed to the subject inside a bag. The subject was asked to remove the object from the bag. The subject was asked to identify the object and to demonstrate the object in each of the positions.

Note that the verbal prompts for partially correct responses described above were permitted to obtain a correct response.

1) Object Identification

Researcher: "Please tell me what the object you are holding is called."

Subject: "A tiger."

Researcher: "O.K."

2) Frontal Position

Researcher: "Please show me the front of the tiger (or use the term specified for the object by the subject if an incorrect response is given for object identification)

Subject: Holds the tiger facing the researcher.

Researcher: "Thanks for doing that."

"Good effort" (for an incorrect response)

Haptic Rehearsal Trial #1

Researcher: "Let's try it again" (followed by a hand over hand physical assist to reorient the stimulus symbol to the specified position. The subject is asked to put the tiger back into the bag and then asked to take it out again and to show the front position of the tiger.)

Researcher: "Put the tiger back into the bag."

Subject: (Places tiger back in the bag).

Researcher: Take the tiger out of the bag. Please show me the front of tiger."

Subject: Holds tiger facing the researcher.

Researcher: "Thanks for doing that."

(If response is incorrect, continue with Haptic Rehearsal Trial #2 and continue until correct response is achieved or a total of 3 rehearsal trials have been attempted.

Remaining Positions

Repeated procedures were used for the frontal position using the folowing initial verbal prompts:

3) Behind Position

Researcher: "Please show me the tiger from the behind position."

4) Sideways Turned Right Position

Researcher: "Please show me the tiger in the sideways turned to the right position."

5) Sideways Turned Left Position

Researcher: "Please show me the tiger in the sideways turned to the left position."

6) Top Position

Researcher: "Please show me the tiger from the on top position."

7) Bottom Position

Researcher: "Please show me the tiger from the bottom position."

Phase #3- Spatial Matrix Matching

The subject retained possession of the tiger and the researcher reintroduced the photographic array and asked the subject to match the position of the tiger he/she is holding with each of the orientations depicted in the photos numbered 1,2,3,4,5, and 6. The following script was used:

Researcher: "Look at photo #1. Please match the tiger to the position you see it in the photo. Place the tiger on top of the photo to make the match.

Subject: Demonstrates correct response by placing the tiger on top of the photo in the correct position specified.

Researcher: "Thanks for doing that."

This procedure was repeated for photos 2,3,4,5,and 6. This ended Treatment Trial #1. These procedures were followed for each of the subsequent trials, Trial #2 used the cow stimulus and Trial #3 used the raccoon stimulus.

Treatment trials #4,#5,#6 wooden numerals. The same procedures were followed as in Trials #1,#2 and #3, using wooden numerals, and grouped; (a) Trial#4 Straight- 1, 4, 7,; #5 Trial#2 Curved -2, 3, 5,; and #6 Closed- 6, 8, 9. Verbal prompts for partiallly correct responses on object identification included;

Researcher: "Look at photo #1. Please tell me what the object you see is called."

Subject: "A number...numeral"

Researcher: "O.K. Please tell me what that number...numeral is called."

Subject: "It is a _."

Researcher : "O.K."

This was repeated for photos 2,3,4,5, and 6.

Treatment trials #7, #8, #9 wooden letters. The same procedures were repeated as in Trials #1-#6, using lowercase wooden letters that were grouped: (a)Trial #7 Open/Short- n, u, v, m, w; (b) Trial #8 Closed-b, d, p, g, q; and (c) Trial #9-Open h, y, j, f, t. Verbal prompts for partially correct response for object identification included the following;

Researcher: "Look at photo #1. Please tell me what the object you see is called."

Subject: "A letter."

Researcher: "O.K. Please tell me what that letter is called."

Subject: "It is called a__."

Researcher: "O.K."

Photo arrays were arranged such that photo #1 depicted the frontal view of the stimulus. The remaining 5 photos were randomly arranged (to eliminate the possibility that the subject would be able to predict the spatial position of the stimulus based upon its location in the photographic array).

It was hoped that these methodological procedures, which had been developed provided results which are valid and reliable.

CHAPTER 4

RESULTS

Statistical Comparisons

The real differences observed in the raw data for combined pre- to post-test subtest scores revealed an increase in the experimental group mean from 286.6 to 441.2. There was also an increase in the mean for the control group from 314.4 on the combined pre-test subtest scores to 442.9 on the combined post-test subtest scores.

A Kolmogorov-Smirnov Two-Sample Test revealed a significant difference between the experimental and control group pre-test scores for the reading subtest ($p \leq 0.05$). The mean for the experimental group on the reading pre-test subtest was 25.9. The mean for the control group on the reading pre-test subtest was 80.09. This result demonstrates that the two groups were different, as hoped, at the outset.

A Wilcoxin Matched Pairs Signed Rank Test revealed no significant ($p \leq 0.05$) differences for the pre-to post-test comparison of reading subtest scores for the experimental group. However there was an educationally significant difference as their reading post-test scores increased from a mean of 25.9 to 31.4. As expected, there were no significant differences ($p \leq 0.05$) for pre-to post-test comparisons of reading scores for the control group, despite a smaller change in their mean which increased from 80.09 to

83.3. Post-test comparisons for experimental to control group revealed significant differences ($p \leq 0.05$).

The reading subtests selected for the statistical analysis fall within the category of literacy skills. In hindsight, the slight improvement in reading subtest scores is not an unpredictable result given the brief period of intervention of approximately two and-a-half hours of instructional time over a period not exceeding seven school days. The fact that scores improved is noteworthy. While this increase in scores may be due to variables other than the independent variable, the scores may in fact be underrated if the instruments used to measure reading ability were not reliable, valid or sensitive enough to accurately assess oral reading performance over a short time span. The strong real differences observed for the group means in the raw data introduced the possibility that significant differences may be found in the category of subtests designed to measure pre-literacy skills. Subsequently a post-hoc analysis was performed for the pre- and post-tests for the printing letters subtest, and is discussed following the recommendations.

One of the most striking practical implications of this study was the time lost to classroom instuction and the amount of direct adult supervision required to conduct the intervention. Intense one-to-one instruction in a hands-on environment wass needed to facilitate the haptic rehearsal through ongoing corrective physical and verbal feedback.

This required the instructional support of a teacher, teacher aide, trained volunteer or clinician. Given the limited human resources available at the classroom level, such an intervention may not be realistic. A clinical environment such as a diagnostic learning center, attended outside of the regular school day may be a more suitable environment in which to deliver the intervention.

Seven critical variables not considered in the research design included; the constraints of time in selecting subjects who met all of the eligibility criteria for each of the experimental and control groups, the sensitivity of the instruments selected to assess reading skill performance on the pre and post-test subtests, the homogeneous streaming of grade two students into classroom groupings, the dual track French/English school site, experimenter error for the order of treatment conditions, subject boredom, fatigue and hunger, the delay in start date for the study which resulted in the study coinciding with the Festival du Voyager Week during days eight through eleven, the inclusion in the study of two subjects with ADHD, one on medication and the other off medication, and, novelty effects for post-test administration by the two research assistants.

Research Questions Reviewed

In response to the research questions:

Question #1- There was statistically significant evidence ($p \leq 0.05$) consistent with a VGM found in the between groups comparisons for both the pre and post-test scores for the reading subtest with the control group having higher scores than the experimental group. This meant that the two groups were distinctly different from each other at the outset with the control group scoring higher than the experimental group. This provided a pre-requisite for the rest of the experiment.

Question #2- There was statistically significant evidence ($p \leq 0.05$) consistent with the lack of control of the VGM in pre-logical thinkers found in the between groups comparisons for both pre-and post-test scores for reading subtests with the experimental group having lower scores than the control group. This meant that the frequency of errors made when subjects read graded passages out loud were higher for the experimental group and that subjects reached a reading frustration level that was lower than the reading frustration level of the control group. Reading sub-test scores were derived by counting the number of errors made and subtracting that number from the total number of words in the passage. A frustration level was reached when the subject made three or more errors on any given passage.

Question #3- There was no statistically significant evidence ($p \leq 0.05$) in the analysis of literacy skill performance on the reading subtests that the VGM can be brought under control by pre-logical thinkers. This meant that while real differences showing improvement for the experimental group were observed, these differences were not statistically significant. Therefore, the hypothesis that the VGM may be brought under control by pre-logical thinkers having used haptically enhanced instructional strategies may be false. However, a post-hoc analysis was conducted to respond to this question for the pre- literacy skill performance on the printing letters subtests. A statistically significant difference ($p<0.05$) was found between experimental group pre- to post-test comparison.

Question #4- There was no statistically significant evidence ($p\leq0.05$) found for the literacy skill performance on the reading subtests to support that having the VGM under the control of pre-logical thinkers may improve literary and numerary skills. This meant that the strong early reading abilities of the control group were as a result of some unknown factor other than VGM control. For a response to this question for the statistically significant evidence ($p<0.05$) that was found for pre-literacy skills on the printing letters subtests see the post-hoc analysis.

Discussion

Control Group. Observations recorded during the treatment conditions indicated that subjects in the control group demonstrated verbal rehearsal (repeating the researcher's verbal prompt) and self-talk strategies (e.g. "It goes like this."). They identified stimuli correctly when presented regardless of orientation before reorienting them to the frontal position, and appeared to use their hands to perform kinesthetic visualizations of the reorientation required to correctly identify the pictoral stimuli. These subjects developed the tendancies to reorient the haptic enhancers (stuffed toys , wooden numerals and letters) to the frontal position before orienting them to the desired position to create a match with the pictorial stimulus. They became aware of their errors and either automatically self-corrected or were able to produce the correct response with only a verbal prompt given by the researcher. Additionally they appeared to make informed guesses when their responses were not certain and in this way had a lower frequency of repeating the same mistakes than the experimental group did. Subjects in this group approached the tasks enthusiastically, remained focussed, interested and completed the sessions without complaints of being tired. Subjects in the control group required less time to produce their responses to the stimili presented in the treatment conditions than the subjects in the experimental group did. On the average, the control subjects required 20 minutes and 38 seconds less time than the experimental subjects to complete their tasks. The total time required for the control group to complete the three treatment conditions was 703 minutes and 30 seconds, with a group mean of 70 minutes and 48 seconds and a group median of 69 minutes and 12 seconds. Subjects in the control group made a total of 913 identification errors with a group mean of 150.3 and a median of 168. Three hundred and sixty-four prompts were given by the researcher during the haptic rehearsal strategies and the subjects made 99 self-corrections, 89 inversions, 154 reversals, 32 vertical matches for horizontal stimuli, 33 horizontal matches for vertical stimuli and 17 null responses.

<u>Experimental Group.</u> Subjects in the experimental group did not demonstrate verbal rehearsal strategies or use self-talk to generate their responses to stimuli. Stimuli were identified correctly regardless of the orientation with a lower frequency than the control group and without the concommittant reorientation of that stimulus to the frontal position. These subjects did not use their hands to perform kinesthetic visualizations to produce the reorientations required to create a correct match when identifying pictoral stimuli. There was a higher frequency of the incorrect identification of the stimulus when the subject removed it from the bag and a higher frequency of trials during haptic rehearsal. Fewer of these subjects developed the tendancy to reorient the stimulus to the frontal position before the

orientation to create the desired match with the pictorial stimulus. There was a high frequency of random guessing when the response to a stimulus was unknown. Some subjects failed to become aware of their errors despite the repeated haptic rehearsal which was provided. There was a higher frequency of trials for haptic rehearsal, more errors were made than for the control group with a lower frequency of correct responses to verbal prompts than in the control group. More self-corrections were attempted than in the control group but many of these resulted in errors. Despite high levels of energy and high mobility (e.g. swinging legs, drumming fingers rocking in chairs) fewer subjects in this group had the same high level of enthusiasm in their approach to the treatment conditions than the control group did. There was a high frequency of off-task behavior (e.g. daydreaming, talking) that required refocussing of the subjects' attention by the researcher to the task at hand. Some subjects complained of being bored and tired and required verbal encouragement to complete their tasks. The total time required for this group to complete the three treatment conditions was 898 minutes and 18 seconds with a group mean of 90 minutes and 6 seconds and a group median of 85 minutes and 54 seconds. Subjects in the experimental group made a total of 1641 identification errors, with a group mean of 249.9 and a median of 249. Five hundred and seventy-five prompts were given by the researcher during the haptic rehearsal strategies and the subjects made 128 self-corrections, 120 inversions, 164 reversals, 32 vertical errors for horizontal stimuli, 32 horizontal errors for vertical stimuli, and 52 null responses.

Individual Subjects. Direct observation of subjects and subsequent review of accumulated treatment condition data revealed an emergence of two specific types of visual and concrete error patterns. Firstly, a pattern of receptive and expressive inverting/reversing behavior was observed. Secondly, a pattern of receptive and expressive vertical/horizontal rotation was observe. For the purpose of this discussion two subjects were selected who each expemplified one of these error patterns. Subject #5 from Group#2 typified the inversing/ reversing behavior which was reflected in the treatment condition score which totalled 253. The subject was observed to make 137 identification errors, received 60 prompts, made 8 self-corrections, 25 inversions, 32 reversals, 3 vertical responses to horizontal stimuli, 4 horizontal responses to vertical stimuli and zero null responses. Subject #9 from Group#1 typified the vertical/horizontal behavior which was reflected by treatment condition score which totalled 252. The subject was observed to make 142 identification errors, received 65 prompts, made 14 self-corrections, 14 inversions, 19 reversals, 18 vertical matches to a horizontal stimulus, 7 vertical matches to a horizontal stimulus, and 1 null response.

Additionally specific types of behavior emmerged which were observed to be indicative of successful responses to stimuli. These included verbal rehearsal, the use of hands to mentally rotate objects, returning to the frontal position to begin the orienting process to achieve a change in position, visualizing before responding and the spontaneous self-correction of inaccurate responses without verbal or physical prompts from the researcher. Subject #9 in Group#2 typified these types of behavior which was reflected by the treatment condition score which totalled 40. This subject was observed to make 24 identification errors, received 11 prompts, made 9 self-corrections, 2 inversions, 10 reversals, 1 vertical match for a horizontal stimulus and 1 horizontal match for a vertical stimulus and gave zero null responses.

Conclusions

The data from this study are inconclusive. The behavior of the subjects during the treatment conditions provided insight into how early years students function to access and use their spatial orientation skills to develop pre-literacy and literacy skills. Subjects achieved improved treatment condition scores and performance times through subsequent trials. For example experimental subject #4 in Group#1 made the following identification errors; T1=116, T2=96, T3= 75 (where T means trial). The prompts given were; T1=35, T2=29, T3=14. Inversions made by the subject were; T1=6, T2=4, T3=1. Reversals made; T1=1, T2=4, T3=4. Vertical responses to horizontal stimuli; T1=2, T2=2, T3=0. Horizontal responses to vertical stimuli; T1=2, T2=0, T3=0. Null responses include; T1=24, T2=3, T3=1. Subject #4 in Group#1 recorded the following times; T1(a) 32:09, T1(b) 22:52, T2(a) 21:29, T2(b) 18:29, T3(a) 15:58, T3(b) 12:53 for a total of 123 minutes and 48 seconds.

These observations indicate that the subject, while initially making many errors during T1 (116) was able through the repetitive process of the physical assistance of the haptic rhearsal strategies was able to reduce the number of errors by T3 to 75. Time to complete the treatment was also observed to improve from 55 minutes and one second in T1 to 27 minutes and eleven seconds in T3. Whether the subject gained access to the VGM and was able to control it for the spatial orientation exercises is inconclusive. However there was indeed a great improvement in this subject's ability to remember through the tactile mode used in the haptic rehearsal strategies indicating some form of learning had taken place.

As a second example control subject #1 in Group#2 made the following identification errors; T1=43, T2=17, T3=4. The prompts given were; T1=17, T2=7, T3=1. Inversions made by the subject were; T1=2, T2=0, T3=3. Reversals made; T1=0, T2=4, T3=1. Vertical responses to horizontal stimuli; T1=0, T2=1, T3=0. Horizontal responses to vertical stimuli; T1=5, T2=0, T3=0. Null responses include; T1=0, T2=0, T3=0. Subject #1 in Group#2 recorded the following times;

T1(a)=12:07, T1(b)=9:53, T2(a)=7:32, T2(b)=5:27, T3(a)=6:16, T3(b)=6:25 for a total time of 47 minutes and 36 seconds.

These observations may indicate that the subject in the control group had access to and control of the VGM which enabled him/her to achieve better performance results for accuracy and time on the treatment conditions. Certainly the ability to focus attention to the task at hand, verbal rehearsal,self-talk, reorienting the object to the frontal position, using visual imagery, making educated rather than random guesses and remaing seated throughout the procedures were observed to have a positive effect upon the subject's score and performance of the treatment conditions.

Recommendations

Further research in this field of inquiry is needed to produce consistent results. The following steps should be taken to improve the research design and methodology before attempting a second research project:

1). Select instruments for assessment which are more sensitive to achievement over a brief period of time which have been professionally developed, tested for reliability and validity and norm or criterion referenced.

2). Build in more time between the sample selection and the start date of the study so that students who fail to meet all of the criteria for inclusion in either group can be replaced with another subject randomly selected from the available population.

3). Ask the school staff how the students are grouped within classrooms, heterogeneously or homogeneously and closely review the baseline test results. Two students perceived as control group candidates in classes streamed for low to average performance did not perform as well in the study as two students perceived as experimental group students in a class streamed for average to above average performance.

4). Establish clearer guidelines for the teachers who are putting forward student names for the sample selection, improve the pre-literacy screen to better observe the group inclusion criteria and replace any subject who does not meet or exceeds the criteria for group inclusion with a subject that does fall soundly within the parameters for one of the two groups.

5). Reduce the number of stimulus items within each of the treatment conditions to reduce time required to complete the tasks to reduce variables of boredom and fatigue.

6). Build in more flexibility in terms of the time frame so that the study can be moved up or set back to avoid a major school event such as a festival.

7.) Build more flexibility into the schedule for test administration by training a different research assistant to conduct each of the following: baseline screen and pre-test, treatment condition #1, treatment condition #2, treatment condition #3, and post-test.

8). Incorporate training in self-talk, the use of hands to mentally rotate objects, the return to the frontal position as a first step in rehearsal, visualizing to create mental imagery before responding, and positively reinforcing spontaneous self-corrections of inaccurate responses into the training procedure.

9). Confounding factors such as lack of attention to task, hypermobility, and self-depricating verbal behavior may be a cluster of symptoms associated with some other disorder such as ADHD. It is important to be informed of this type of learning disability so that students diagnosed with a serious behavioral/attention disorder regardless of whether they are on or off their medication can be eliminated from the sample. Or if there are enough subjects available, to treat them as a seperate group, Group#3 to compare the effects that haptic rehearsal strategies have on the development of pre-literacy and literacy skill for attention defecit and hyperactive children. Alternatively a calming strategy such as a guded imagery could be delivered before the treatment to calm and relax all of the subjects.

Post-hoc analysis

A Kolmogorov-Smirnov Two-Sample Test revealed a significant difference between the experimental and control group pre-test scores for the printing letters subtest ($p \leq 0.05$). The mean for the experimental group on the printing letters pre-test was 42.4. The mean for the control group on the printing letters subtest was 51.4. It is assumed that because these groups demonstrated real as well as statistically significant differences on this component on the pre-testing that similar differences might exist for the other pre-test subtests.

A Wilcoxin Matched Pairs Signed Ranks Test revealed significant ($p \leq 0.05$) differences for the pre- to post-test comparison of the printing letter subtest scores for the experimental group. The mean for the experimental group for the printing letters post-test subtest was 49.7. Significant ($p \leq 0.05$) differences for the pre- to post-test comparison of the printing letters subtest scores for the control group were also indicated. The mean for the control group for the printing letters post-test subtest was 52. Post-test comparisons for experimental to control group revealed significant differences ($p \leq 0.05$).

The printing letters subtest falls within the category of pre-literacy skills. The significant improvement was a predicted result, and can be attributed to the effects of the independent variable, haptic rehearsal strategies on the dependent variable, pre-literacy skill performance.

<u>Summary</u>

The test scores for the printing letters subtests provides evidence that the concrete manipulation of three-dimensional wooden letters through haptic rehearsal strategies results in improved pre-literacy skill performance. Consistent with the proposed hypothesis, subjects gained access to and gained control of some form of a phenomenological spatial orientation device, and with haptic rehearsal were able to develop self-correcting tendancies to reduce the frequency of inversion, reversal, transposition and substitution errors. This improvement in literary skills is believed to be a result of the effects of the independent variable on the dependent variable and provides evidence that having the VGM under the control of pre-logical thinkers does improve pre-literacy skill performance.

Conclusion

These results are inconsistent with the statistical results obtained for the pre- to post-test comparison within groups for the reading subtest. Further research is required to determine whether additional evidence can be found to support the VGM hypothesis.

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APPENDIX A

GLOSSARY OF TERMS (Conceptual* and Operational)

autonomic nervous system (ANS)- ganglia, nerves, and plexus which regulate activities of the viscera, heart, blood vessels, smooth muscle, and glands (Brown, 1976).

axon- neuron fibers which conduct impulses away from the cell body; long neuron fibrers (Brown, 1976).

basal ganglion- a specialized group of nuclei located in the central nervous system consisting of masses of gray matter significant in motor control (Kuehn, Lemme & Baumgartner, 1989).

bits- information such as differentiated sounds, or visual stimuli. The central nervous system is capable of processing at most seven bits of information at one time (Csikszentmihalyi, 1990).

central nervous system (CNS)- the encephalized portion of the nervous system and its contiguous caudal or tail end which includes the brain and spinal cord contained within the skull and spinal cord (Brown, 1976).

chunking- the automation of a simple function like driving a car, leaving the mind free to deal with more data. In this way stimuli are compressed thereby expanding the processing capacity of the conscious mind (Csikszentmihalyi, 1990).

Concrete Operational Period- within Piaget's (1954) theory of intellectual development. A stage between eight to eleven years involving a child's performance of the logical operations adding, subtracting, seriating, classifying, numbering, and reversing (Sund, 1976).

convolutional integrals- linear mathematical equations describing the wave forms of the brain's electrical potentials that result in susperposition, the holographic hypothesis of brain function (Pribram, 1971).

cortical cells- the cells found in the cerebral visual cortex. There are two specific cell types; large pyramid cells dominate the motor areas while sensory areas are composed of simply configured granular cells (Rahmann & Rahmann, 1992).

*dependent variable- a single dependent variable, literacy skill performance with three levels; ability to gain control of the virtual gyrostatic mechanism to spatially orient objects, ability to recall visual information holographically, and improved numerary and literary skills (Dewick, 1998).

dyslexia- the innate, inborn inability to learn to read (Benson, 1981). A selective reading disorder associated in 90% of the cases with a family history of speech defect and/or reading and spelling difficulties (Brierley, 1994). School age children experiencing reading failure who have average to superior spatial ability with a preponderance of right-hemisphere processing and a relative left-hemisphere deficiency (Denckla, Rudel, and, Broman, 1982).

electrophysiological research- the investigation of the electrical characteristics of organismic function (Brown, 1976).

encode- the storage of information in memory by forming a representation of stimuli utilizing a device or encoding schema which relies upon prior knowledge and experience to spatially reference an internal register or domain (Carey & Diamond, 1982).

Formal Operational Period- within Piaget's(1954) theory of intellectual development, a stage from twelve to fifteen years involving a child's performance of hypothetical, propositional, and, reflexive thinking (Sund, 1976).

Fourier transform- mathematically, a Fourier transform converts a function of time f(t) into a function of frequency F(jw) where the j indicates that it is a complex function of frequency. A Fourier transform can convert a signal from the time domain to the frequency domain or from a spatial locational domain, (the coordinates in space) to a frequency domain (Prideaux, 1998).

Fourier-like transformations- in holographic memory theory the dendritic process by which stimuli are encoded and remembered. Sensory modality data are stored in the spectral (or frequency) domain, distributed over a region of the brain with specific cells responding to spatial frequencies of visual stimuli (Prideaux, 1998).

ganglion; ganglia- a group of peripheral neurons found in the peripheral nervous system (PNS)(Brown, 1976).

ganglion cells- retinal cell fibers of the optic nerve (Brown, 1976).

geniculo-striate system- one of two pathways (the other being the tectocortical pathway) by which visual information travels to the cortex. Ganglion cell fibers connect onto a collection of cells, the lateral geniculate nucleus. The fibers of which project onto cells in the visual cortex carrying information from the eyes to the brain. It plays an important role in processing information carried by small spatial details and shapes (Spoehr & Lehmkuhle, 1982).

*haptic enhancers- three dimensional symbols which can be manipulated by the subject to store information about those objects in their two dimensional form through a process of holographic memory including; stuffed animal toys, wooden numerals and letters (Dewick, 1997).

*haptic memory- the earliest type of memory where learning occurs through the experience of touching and manipulating the subject's environment forming haptic perception. The storage and retrieval of sensory data which is input physically (Dewick, 1997).

haptic perception- information perceived through touch and kinesthesis. Touch provides feedback when an object is manipulated. Stimulii are received through the skin by three types of sensory receptors. Thermoreceptors respond to heat and cold. Noreceptors respond to intense pressure, heat and pain, and mechanoreceptors respond to changes in pressure. Kinesthesis describes awareness of body and limbposition (Storey, 1998).

*haptic rehearsal- the procedure or repetetive process whereby the subject manipulates or is assisted by the researcher to manipulate the haptic enhancer, turning and rotating the object in until the correct match with the form found in the photographic stimulus and the target stimulus is reached (Dewick, 1997).

*haptic re-orientation- achieving a match during haptic rehearsal, a subject is guided verbally and physically to reorient the haptic enhancer to the singular perspective, aknowledged in the printed form and observes the shift in perspective or alternative point of viewing the letter or numeral shape (Dewick, 1997).

holograms- a precise interaction between the patterns of energy which excite the recpetor cells and the spontaneously occurring neuronal potential changes of recpetor units which create image forming properties, called superposition. This additional mechanism is available in the junctural patterns of neural activity which can display image forming properties akin to optical information processing systems (Pribram, 1971).

holographic memory (HM)- the hypothesis on brain function for perception in which superposition (spatial interactions among phase relationships of neighboring junctural patterns) occurs in neuronal aggregates creating the brain's imaging mechanism (Pribram, 1971).

holographic memory model (HMM)- a brain theory model of memory proposed by van Heerden (1963) and Pribram (1971) in which a holographic component is believed to be part of thinking. In this model, holographic representations are associative mechanisms which instantaneously perform the cross-correlations attributed to thought in the problem solving process. Thought is the search in holographic memory to resolve uncertainty and holograms are catalysts of thought (Pribram, 1971).

*imaging system- the way in which the nervous system creates visual images from stimuli and reproduces visual images from memory (Dewick, 1997).

*independent variable- a single independent variable, visual/haptic rehearsal enhancement with three levels; spatial-orientation identification, manipulative re-orientation rotation, and spatial matrix matching (toys, wooden numerals and letters)(Dewick, 1998).

intraneurosensory learning- information received through one learning system and transduced into only one cognitive modality, wherein the data is not translated into the language of other cognitive complexes (Flaro,1989).

integrative neurosensory learning- using all cognitive modalities simultaneously so that all systems are brought to bear upon the input (Flaro, 1989).

interneurosensory learning- when input data is processed initially in one cognitive modality system and then is transduced into a different representational system prior to an output response (Flaro, 1989).

Levels of Processing Model- The human visual information processing system uses sensory and cognitive mechanisms divided qualitatively into two levels; the control processes used to process information including identifying components and retreiving information and memory (Spoehr & Lehmkuhle, 1982).

*literacy skill performance- a subjects' score on a two-form Test of Literacy Skills, an instrument developed for pre and post-test measures of subjects' abilities to recognize sight words, oral reading comprehension, mental computation, numeration, missing elements, puzzle, printing and identifying letters and numerals, stimulus and journal writing (Dewick, 1998).

long-term visual-spatial memory- within the information processing theory of learning there exists a long-term memory store in which permanent records of scenes, objects, and experiences are stored without the need for constant, active rehearsal of that information. Visual spatial refers to items stored visually through pattern recognition (Spoehr & Lehmkuhle, 1982).

nerve- a bundle of neuron fibers traveling in the peripheral nervous system (PNS), which refers to all neural tissue outside of the central nervous system (CNS) including the brain and spinal cord (Kuehn, Lemme & Baumgartner, 1989).

nervous system- neural tissue where specialized neurons take three forms; differentiation (receptors, integrators, motor neurons), centralization (clustered cell bodies- plexus, ganglia, nuclei, axonal fibers organized as nerves), and encephalization (where most of the ganglia are localized at one end of the organism). The nervous system is divided into parts according to location in the body- the CNS, PNS and ANS which differ in structure and function (Brown, 1976) (see Figure 1).

*neural virtual gyroscope- a hypothesized brain mechanism such as a feature or function either physiological or phenomenological which acts upon visual stimuli by orienting the perspective or point from which the mind views or sees that stimuli, and akin to properties of the physical gyroscope (Dewick, 1998).

*neural hologram- the model of holographic memory process proposed by van Heerden (1963), and Pribram (1971) which explains the brain's electrical potentials in the mechanical wave forms and convolutional integrals of the *physical hologram* (Dewick, 1998).

neuron(e)- an individual nerve cell which is the basic structural and functional unit of the nervous system (Brown, 1976).Each neuron has three components; dendrites, soma or cell body and a single axon. The dendrites receive stimulation (inhibitory or excitatory) and convey it to the cell body. The cell body contains the nucleus, motochondria, Nissl substance, and Golgi apparatus. (see Figure 11). The dendrites and cell body are the receptor zone. The axon is the conducting zone. Electrochemical conduction occurs when molecules move across the membrane that surrounds the neuron. There are two types of axons; myelinated and unmyelinated (Kuehn, Lemme & Baumgartner, 1989).

neural ganglia- groups of cell bodies in PNS or nerve center for intercommunication (Kuehn et al., 1989).

neural nucleus- groups of cell bodies that lie in the CNS forming a nerve center or point of intercommunication (Kuehn et al., 1989).

neuron theory- the view that neurons are structurally independent, but connected functionally (Brown, 1976).

neurophysiological approach- a biomedical investigation of memory formation through the molecular facilitation in synapses. Founded within the theory that memory-specific protein compounds are necessary for long term memory encoding and storage in neuronal networks, but not for short-term memory (Rahmann & Rahmann, 1992).

*parallactic process- interference effects in optical information processing systems which create virtual images, or exact multi- dimensional reproductions of the original scene (Dewick, 1997).

parallax- the reconstruction of a visual scene producing a virtual image that has all the visual properties of the original scene. Binocular parallax- parallax cued by binocular vision. Motion parallax- parallax cued by motion stimuli (Pribram, 1971).

parasympathetic nervous system (PNS)- craniological division of the autonomic nervous system (ANS) organized with ganglion near or in the organ being innervated and usually induces effects opposite those of sympathetic peripheral nervous system (PNS). PNS acts outside of the CNS in a specific manner on target organs and results in inhibition of heartbeat, facilitation of stomach contractions and secretions, and constriction of pupils. PNS work in unison with SNS to maintain integrity of organism (Brown, 1976).

peripheral neurons- neurons belonging to the peripheral nervous system (PNS)(Brown, 1976).

*physical gyroscope- technology used in aircraft to navigate, orienting the ship to horizon (Dewick, 1997).

*physical hologram- the photographic record obtained through the holography technique originally invented by Gabor (1949). Images were reconstructed by creating an interference pattern with coherent background wave a refracted light waves, to store both both amplitude and phase information, which is then combined with a transilluminated coherent light source to create a virtual image (Dewick, 1998).

*pre-literacy skill performance- a score obtained on a battery of informal tests to assess degree of control of VGM in subjects and includes; backwards verbal spelling, upside down image recognition, reading mirror images and logical reasoning, used as basis for assignment of subjects to groups (Dewick, 1998).

*pre-logical early years students- subjects who have not developed to what Piaget refers as The Formal Operational Period, who are between seven or eight chronological years attending grades two or three (Dewick, 1998).

*pre-logical thinking abilty- a score obtained on selected tasks from diagnostic instruments derived from Piagetian theory used to assess subjects' degree of control of VGM. The second of two conditions used as a basis for assignment of subjects to experimental groups (Dewick, 1998).

physiological psychology- the study of how body structures and functions affect and control the overt and subjective behavior of an organism (Brown, 1976).

psychophysical approach to visual perception; psychophysics- the study of the relationship between physical stimuli and sensory experience (Brown, 1976).

quantum; quanta- the basic unit of light transmission in *quantum theory* (Dewick, 1997).

quantum theory- the neuron theory that the NS functions as a set of conducting units. Each cortical point, cell, or cell aggragate is specialized for a unique function. The integration for behavioral and psychological processes is accomplished by the inborn presence of, or the establishment by experience of permanent connections between neurons (Pribram, 1971).

*recode- the information previously stored in memory is retrieved, manipulated through multiple encodings and rehearsal and then restored in memory (Dewick, 1998).

*selected tasks- structured activities in which the subject utilizes haptic enhancers to construct holographic memory images which are then brought under the control of the gyroscopic mechanism enhancing long term-term memory recall (Dewick, 1998). The treatment conditions of this study in which subjects utilize haptic enhancers to perform academic tasks related to numeral and letter recognition.

*self-correction- the subject's ability to develop an awareness that an error has been made when responding to a visual stimulus, the subject evaluates the error made and uses strategies to correct existing patterns of frequently repeated mistakes such as the reversal, inversion, transposition and substitution of letters, numerals and shapes (Dewick, 1998).

sensory psychology- the study of stimulus-response relationships explained by physical energies such as the transformation of stimulus input to a receptor into a neural signal (Brown, 1976).

sensory register- in the visual system a sensory information store that is a very short-lived memory that allows the system to maintain information about a visual stimulus for a few fractions of a second after it has disappeared. This kind of memory gives the sensation that a briefly presented stimulus persists longer than it is actually present (Spoehre & Lehmkuhle, 1982).

serotonin -hydroxytryptamine- a substance present in neural, intestinal and vascular tissue thought to have neurotransmitter functions (Brown, 1976).

superposition- a phenomenon which occurs when nerve impulses arrive simultaneously at neighboring locations and interactions of an additive or subtractive nature take place.. Spatial interactions among phase relationships of neighboring junctional patterns. An image forming property akin to those of optical processing systems such as holograms. In quantum theory, a quantum of light exerts a force on its neighbor causing an interaction effect. Superposition is explained by a series of linear equations called convolutional integrals used to describe interactions among wave forms (Pribram, 1971).

*symbol- a visual stimulus in the form of a three-dimensional represenational symbol of concrete form which may be a toy animal, letter or numeral (Dewick, 1998).

sympathetic nervous system (SNS)- thoraciolumbar division of the ANS which induces effects opposite those of parasympathetic nervous system (PNS). SNS is organized to form a connected chain at ganglia that run parallel to the spinal cord. Fibers arising from these ganglia synapse with nerves that activate autonomic structures in the body; contraction of arteries, acceleration of heartbeat, inhibition of stomach contractions and secretions, and dialation of pupils. The SNS tends to trigger all systems it innervates at once. Works in unison with the PNS to maintain maximal integrity of organism (Brown, 1976).

*three dimensional forms- concepts such as letter and numeral recognition acquired through the association of solid concrete objects which represent that concept (Dewick, 1998).

*virtual gyrostatic mechanism (VGM)- a theoretical model of a spatial orientation device available to the subject which can be utilized to facilitate short-term memory procedures by manipulating holographic memory images or holograms (Dewick, 1997). From gyrostatic, a branch of physics that investigates laws governing rotation of solid bodies and virtual, having effect but not form (Freeze, 1997).

virtual image- an image of a visual stimulus or visual scene which is created through the physical holographic process (Pribram, 1971).

visual information processing- the entire process by which human beings receive visual information and adjust their behavior on the basis of that information (Spoehr & Lehmkuhle, 1982).

visual memory- an anlysis of perceptual and sensory phenomena involving the use of prior knowledge to make decisions (Spoehr & Lehmkuhle, 1982).

*visual spatial orientation- multiple perspectives or points of viewing visually represented concepts. Imaging on the brain as opposed to the visual image of the object (Dewick, 1997).

window of opportunity- the crucial years of intellectual stimulation fom birth to six years of age when children learn with naturalness and ease. Cognitive psychologists support the view that an individual's achievement in life depends upon what has been learned before the age of four years (Pines, 1966). The brain's greatest growth spurt draws to a close around the age of ten years. The neural connections from the retina to the visual cortex occur in infancy. The learning window for math and logic is birth to four years, for music three to five years and a series of windows of opportunity exist for language development. For example the window for acquiring syntax closes as early as five years, while the window for adding new words may never close. By the age of one year the neurons for processing speech sounds grow an axon that carries an electical signal which when it reaches the auditory cortex creates a dedicated circuit (Begley, 1996). The ability to learn a second language is highest before the age of one year while the auditory cortex is developing its perceptual map for language (Nash, 1997).

APPENDIX B

CONVERSION TABLE FOR BYTES TO BASE 10

Bytes			Base 10
1000 bits	=	byte	10^4
1000 bytes	=	kilobyte	10^7
million kilobytes	=	megabyte	10^{13}
million megabytes	=	gigabyte	10^{19}
million gigabytes	=	tarabyte	10^{25}
million tarabytes	=	tetabyte/pedabyte	10^{31}

APPENDIX C

CALCULATION FOR LIFESPAN BIT TRANSMISSION BASED UPON RATE OF ELECTRICAL IMPULSE TRANSMISSION FOR LEAST AMOUNT OF TIME REQUIRED TO DISCRIMINATE BETWEEN ONE SET OF SEVEN BITS AND ANOTHER SET OF SEVEN BITS

The following calculation is based upon the shortest amount of time it takes to discriminate between seven bits of information = 1/18th second (Czikszentmihalyi, 1990).

Estimated on the basis of a 16 waking hours per day during which input may be received and a lifespan of 70 years, and a rate of 7 bits in 1/18th second, the human brain may be expected to store a maximum of approximately 185 billion bits of information.

1/18 sec.	x 18 sec.	x 60 min.	x 60 hour	x 16 day	x 364 year	x 70 lifespan
7	126	7560	453600	7257600	2639000000	18473000000

APPENDIX D

CALCULATION FOR HUMAN BRAIN INFORMATION STORAGE CAPACITY IN MEGABYTES OF MEMORY

The following calculation is based upon the estimated Lifespan Bit Transmission Rate of Electrical Impulse Transmission provided in Appendix A. In a lifespan approximately 185 billion bits of information may be transmitted at a fixed electrical rate along neural pathways for storage in memory. To compare this capacity to megabytes of memory the calculation is as follows given 8 bits= 1 byte, 1000 bytes= 1 kilobyte, and 1,000,000 bytes= 1 megabyte of memory.

1.) Lifespan Bit Transmission Rate of Electrical Impulse
    185,000,000,000 bits/8= 23.1 billion bytes.
2.) 23.1 billion bytes/1000= 231,000,000 kilobytes.
3.) 23.1 billion bytes/1,000,000= 231,000 megabytes.

Based on the electrical impulse transmission of input, in a lifespan of approximately 70 years the human brain may be expected to have the capacity to store 231,000 megabytes of information in memory.

APPENDIX E

CALCULATION FOR STORAGE CAPACITY OF MERRIAM WEBSTER'S COLLEGIATE DICTIONARY: TENTH EDITION, 1997 IN MEGABYTES OF MEMORY

This calculation is derived to provide a concrete comparision between the quantity of information stored in a 1559 page dictionary and the calculated Human Brain Storage Capacity presented in Appendix D. To perform this calculation the number of characters (spaces excluded) on a randomly selected page of the dictionary (p.1339) are estimated. This is done by randomly selcting a sample of 10 lines from the page, counting the number of characters per line and calculating an average. The average is then multiplied by the number of counted lines on the page to detemine the number of characters per page. This amount is multiplied by the number of pages. The total number of characters or bits is converted to megabytes. The calculation is a follows:

1.) Number of characters on page 1339= 9858

a) Number of characters in sample;

(53,55,60,53,55,50,08,56,56,42)

b) Average of sample (sum 488/10)= 48.8

c) Lines on page= 202 x 48.8= 9857.6

2.) Estimate of number of characters per page x total number of pages= total number of characters in the dictionary; 9858 x 1559= 15,367,998.4.

3.) Given a single character is synonomous with a single bit;

a) Total number of bits 15,367,998.4/8= 1,920,999.8 bytes.

b) 1,920,999.8 bytes/1000= 1921 kilobytes.

c) 1,920,999.8 bytes/1,000,000= 1.92 megabytes

The calculated capacity for information stored in this dictionary is approximately 2 megabytes. Based on this comparison during a lifespan of 70 years the human brain may be expected to store through electric impulse transmission the amount of information contained in 115,000 dictionaries.

APPENDIX F

FACULTY OF EDUCATION RESEARCH AND ETHICS COMMITTEE APPROVAL FORM

UM

Faculty of Education
ETHICS APPROVAL FORM

To be completed by the applicant:

Title of Study:

Effects of Haptic Rehearsal on Self-Correction of Letter and Numeral Shape Reversals, Inversions, Transpositions and Substitutions by Pre-Logical Early Years Students

I/We, the undersigned, agree to abide by the University of Manitoba's ethical standards and guidelines for research involving human subjects, and agree to carry out the study named above as described in the Ethics Review Application.

Linda Carol Dewick
Name of Principal Investigator (s)(please print)

Name of Principal Investigator (s)(please print)

Linda Carol Dewick
Signature(s) of Principal Investigator(s)

Signature(s) of Principal Investigator(s)

To be completed by Thesis/Dissertation Advisor or Course Instructor (if Principal Investigator is a student):

...e note that by signing this form, you are acknowledging that you have read the completed Ethics Approval Form of the above named student and are satisfied that it is ready for submission to the Research and Ethics Committee.

Signature

Dr. Richard Freeze
Name (please print)

To be completed by Research and Ethics Committee:

This is to certify that the Faculty of Education Research and Ethics Committee has reviewed the proposed study named above and has concluded that it conforms with the University of Manitoba's ethical standards and guidelines for research involving human subjects.

Rosa Bruno-Jofré, Associate Dean Graduate Programs
Name of Research and Ethics Committee Chairperson

14 December 1998
Date

Signature of Research and Ethics Committee Chairperson

Revised 22 September 1997

THE UNIVERSITY OF MANITOBA

Faculty of Education
Research and Ethics Committee

Winnipeg, Manitoba
CANADA R3T 2N2
Telephone: (204) 474-9481
Fax: (204) 474-7551

14 December, 1998

Ms Linda Dewick
87 Woodview Bay
Winnipeg MB R3R 3C9

Dear Ms Dewick:

Thank you for the revisions to your ethics application regarding your study, "Effects of Haptic Rehearsal on Self-Correction of Letter and Numeral Shape Reversals, Inversions, Transpositions and Substitutions by Pre-Logical Early Years Students." I am pleased to inform you that your proposal conforms to the ethics policies and procedures of the Faculty. Accordingly, I have attached a copy of the signed ethics approval form.

On behalf of the Committee, I wish you well in the successful completion of your research endeavors.

Yours truly,

Rosa Bruno-Jofré, Ph.D.
Associate Dean, Graduate Programs

/mp
Attach: Copy of the Ethics Approval Form