DRAFT

INTEGRATING VISION WITH THE OTHER SENSES

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Introduction

"There is no professional who has more power to change a person's life than his optometrist, doing his job properly."

Leo Manas, ca. 1963
Visual Therapy Lecture Notes

Dr. Manas' statement stopped me cold. How arrogant! How egocentric of him…but, how true.

Clinical experience has borne out his declaration time and again over the intervening years since my initial sophomoric outrage. I have repeatedly apologized to him *in absentia*. At the time, he briefly went on to qualify his words, saying that a person's minister was the only exception to that statement. And now, some 35 years and many of life's miles later, I am not so sure that I would include his exception very often at all. Optometrists actually have more opportunity to make pragmatic changes in a person's life than even most clergy persons. It is almost certainly because the domain of the visual clinician is not just the eye, but instead, the *brain*, as an integrated whole.

NOTE:

This paper is separated into two major sections, the first aimed at the optometrist and the visual therapy assistant, with clinical considerations discussed more directly; the second is a review and discussion of the neurobiology research literature as it supports the clinical experience of visual therapy.

SECTION ONE

VISION RULES

If you consider for a moment how much of the brain is anatomically involved with vision, Dr. Manas' remark is even easier to understand. Neuroanatomists tell us that upwards of 50% of the neural tissue is devoted to vision directly or indirectly. And almost incredibly, two-thirds of the electrical activity of the brain is devoted to vision when the eyes are open. Two of three billion firings per second are from the visual sense.[1]

A.M. Skeffington[2], called the "Father of Modern Optometry", repeatedly said in his teaching, "If a person can't see 100%, they cannot ***be*** 100%," and, "A person insecure in his visual state will be insecure in his ego state." Vision is the dominant sense: it provides the brain with over 80% of what it knows. And, according to visual science's arguable grand-pére, Sir Stewart Duke-Elder, the purpose of vision is to guide and direct movement. Added to that, not only Skeffington, but Harmon[3], Getman[4], Renshaw[5], and Kraskin[6] and of course, Gesell[7] said again and again, that all learning is based in movement. The three principles can be combined into one:

"The purpose of vision is to guide and direct learning,
and movement is its medium."

It is very important to realize that vision is a bully: it tries to persuade our brain that what it is sensing through vision is the *only* reality, whether its perception is accurate or not. For instance, take a pair of yoked prisms, 10 prism diopters or more in power, either base-right or base-left. When looked through, these will not only change the apparent shape of a vertical edge, but also how it *feels*. Kinesthesia, because it is servant to visual perception, is bullied by it and the edge will now actually feel bowed to the vast majority of people. Closing the eyes will extinguish the feeling of bowedness, and opening them restores it once again. Vision is integrated with the other senses and dominates them so fully that the brain has to almost stop, figuratively, and weigh the visual input with the proprioceptive, the auditory and to a lesser extent, the gustatory and the olfactory data to be assured that the perceptions we're processing is accurate. As kids might say these days, "Vision Rules!"

FIVE PLUS TWO EQUALS ONE

This paper is written to help you understand what the considerations of the optometrist and visual therapy assistant are in effectively and efficiently rehabilitating visual problems or in habilitating effective visual skills for underachievers. Said a second way, the purpose of this paper is to help you to grasp why it is that the best treatment plans for visual therapy include sensory integration in each activity. A therapist needs to have understanding of how sensory integration operates in the individual and why it enables the patient to develop the highest levels of visual and perceptual efficiency. The integration of the four "external environment" senses with vision in visual therapy requires a bit more of a grand view – a more "whole-istic" consideration of sensory integration and cognitive function. The five senses' input into two brains (the *very* different right and left hemispheres) yields one individualized output (response). And, vision leads the way in the matter.

BRAIN DEVELOPMENT

Let's explore what is known: the concept of the brain being a *tabla rasa* (blank slate) at birth is dying a reluctant death. Too many politically correct behavioral theories were proposed and based on that concept which now require adaptation or abandonment in order to incorporate the revelation that the infant's brain is prewired (pre-loaded, the computer salesmen would say) with programming and even *in utero* experiences. Circuits are laid out in a "best guess" pattern[8] of vision, language, and other functions – actually as independent modules, Gazzaniga[9] believes – and progressively refined by neural activity and driven by experience.[10]

As this is being written, a major (but hardly new) revelation from researcher Gary Marcus at NYU showed that babies at birth are born with instinctual mechanisms for talking and learning language. They are built for learning the rules of language, deducing the very rules of language structure and grammar. Linguists[11] have suspected this about functors (linguistic clauses) in language for decades, at least, but now there is experimental support for these long-standing observations. Along with the previously determined knowledge that babies have an innate, rudimentary sense of shapes and numbers, this adds more nails to the coffin of the *tabla rasa.* We can all stay tuned while the cognitive and linguistic scientists tough it all out. But for the meanwhile, let's look at a simplified schematic of how the brain is laid out.

(Fig. 1)
(Skull with areas)

However, the areas are not isolated. They are integrated with one another in many elementary ways, like this:

(Fig. 2)
(Skull, areas, and tracks)

The observant reader will notice that a few more pathways are represented between the hearing and words/speech areas because for at least two decades, the two areas have been known to be associated and advanced in their relationship.[12] The recent research being reported merely confirms what has been clinically observed. Research[13-17] has revealed that auditory and tactile feedback reinforces visual attention to an area of space. The reverse is true as well: vision reinforces auditory and tactile attention to that region of space. In the vision therapy room, we use geoboards, pegboard patterns, parquetry blocks, buzzer boards, Wayne Fixators, etc., to incorporate the three senses, with vision the leading sense in each activity. This research helps us understand the deep neural value and efficiency of Visual-Auditory-Kinesthetic-Tactual (VAKT) teaching in the classroom as well as in the vision training room.

The pathways are further developed by experience. The greater number of experiences and the better quality of data the individuals encounter, the stronger and more numerous the pathways. The connections are not being formed in willy-nilly fashion, but are promoted and guided by activity. Educator Jane Healy, [18] speaking about the marvelously rich treatment of the brain in learning, points

out that children these days are 75% less active in their play than children were at the turn of the century. The processes of vision and learning cannot be unaffected by this social change. *Play* may actually be thought of as a child's *work* in developing brain processes to higher levels of performance.

Each sense's stimulation reinforces experiences from the others not just by adding to their outputs, but by *multiplying* their response: that is, the output is proportionately much greater than the sum.[19-21] Sometimes optometrists who retest with standardized tests are able to measure progression in virtually logarithmic increases, reflecting this very process.

"Experience shapes brains, but you need to interact with the experience."
Jane Holmes Bernstein, 1988
(reflecting on Weisel's cat car experiment, as cited in Endangered Minds, Healy JM, 1990, p. 80)

VISUAL PROBLEMS

Visual and perceptual problems are *always* problems of systemic stress or sensory and sensorimotor integration, either before or after the fact (in acquired losses). The foundations of most of those failures are based in improper integration of the voluntary and involuntary nervous systems and the sympathetic and parasympathetic branches of the involuntary system. This may occur for any of a number of reasons. Since the visual system is the only site in the body where the voluntary and involuntary nervous systems must work simultaneously, we are bound to see a head-on wreck if the two are not smoothly integrated. The clinician is able to probe those relationships during the 21-point analytical: phorias and #14 and #15 crossed cylinder tests appear to measure stress direction; and ductions, plus the #20 and #21 lens acceptance ranges measure coping skills.

As Skeffington, Getman and others frequently said, "The wreck we measure is the end point of a visual problem, not the problem itself." No, you're right, they really didn't say "wreck", they meant visual problems: refractive error, suppressions, amblyopia, binocular vision disorders, including strabismus. These adaptive conditions are the end points, or in some of the instances, *transitions* toward an end point, of disorders which begin with problems of integration of the neuro-physiological functioning of vision, Ultimately the difficulties wind up in the perceptual/cognitive domain, to some degree. It is not illogical to say that *every* visual problem and adaptation creates performance dysfunction.

(Fig. 3)
(Skeff 4 Circles)

SKEFFINGTON'S FOUR CIRCLES MODEL

In a brilliant move, Skeffington diagrammed the first model of the functional processes from which he believed that vision emerged. (FIG. 3) In an article currently in review and rewrite,[22] I take some pains to explain how the model benefits from some modification and revision (i.e., the anti-gravity response is just one specialized input -- albeit a *very* important one -- from the entire realm of proprioceptive inputs to the brain; and the Speech-auditory process can be more properly seen as an emergent *from* vision, not adding in to it). Flax[23] pointed out how the Identification and Localization

circles were not only the accommodative and vergence functions, but also the *mental decision* to attend, requiring figure-ground discernment and other higher cognitive skills.

The integrative necessities of all the senses and their importance in visual therapy and habilitation (meaning here the enhancement and equipping of vision and perceptual functioning and then, cognition) can be better grasped, I believe, if the clinician and therapist can follow the next set of diagrams.

If the speech-audition circle is inappropriate in the four circle model, just what is the missing link? From all considerations, the missing link is Time. (FIG. 4) *Sight,* of itself is an episodic, instant-like function, but *Vision* is sequential and requires a time-course for the processes of accommodation, convergence/divergence, fusion, for tracking, scanning and cognitive processing (figure-ground, trajectory, pattern matching, et al).

(Fig 4)
(Adapted 4 Circles)

Speech-auditory processing is a separate subset of processes which is greatly dependent upon vision for rapid and accurate development. Speech too, consists of four interlinked processes. (FIG 5). Language specialists tell us how audition is the primary feedback for and modifier of vocalization and that there is a flowing process, not a sound-in-isolation process, as speech therapists are conditioned to use.[12] Proprioception in the speech process consists of the kinesthetic awareness of lips, teeth and tongue in phonemic production (phonemes are the sounds with which language is built) and the growing child must be able to discern and reproduce the sounds and rhythms of his native tongue. Both of these skills are present by as early as 6 months of age, research has shown.[12]

The brain integrates the speech process with the visual process in an elegant, mysterious, even miraculous way. The latest news tends to support this as an intended design function of the brain.

(Fig. 5)
(Speech 4 Circles)

The theoretical overlap occurs in the areas of proprioception and in the mastery of time processing (this involves rhythm, which is a right brain skill, integrated with sequence, which is a left brain skill). Time is easily overlooked as a visual quality, but it is essential for visual tracking, scanning, pursuing, and even in visualization, because visualization and vision use the very same pathways in the brain.

It appears that, neurally, the four circles of vision and the four circles of speech integrate as noted in FIG. 6, and Language, in no simplistic way, emerges from their integration. This interactive relationship helps to explain some of the conceptually difficult results observed by behavioral and developmental optometrists: language and reading-impaired children often experience great spelling and reading performance changes when they are in fact being treated for visuo-spatial problems.

(Fig. 6)

(Six Circles of Language)

Movement skills act to refine oculomotor performance and rhythmical activities appear to further refine and reinforce the quality of the movement skills in general, probably due to of neural pathway development in the corpus calossum. And so, an adequate motor base that underlies vision and speech skills reinforces and enhances the skills that are built upon them. (FIG. 7) This means that the most accurate tracking and scanning, convergence and divergence, accommodation, visual-motor operations, and, perhaps, a more refined figure-ground discrimination. Speech/auditorally, an enhanced motor base would permit more accurate articulation, fluidity, inflection, more elaborate prosody (the melody of speech), and stereophony (the ability to recognize the direction of a sound and to project it back to its source).

(Fig.7)
(Seven Circles Of Reading/Writing)

THE AUDITORY INTEGRATED WITH VISION

Reading is built upon the integration of these sub-skills when the person decodes graphic representations of the sounds ("graphemes" decoded into "phonemes") and *writing* is the encoding of sounds into letters ("phonemes" coded into "graphemes"). As someone else said, "*Letters* don't make words, *sounds* make words." The more efficiently a child masters both processes, the more proficient a reader (s)he will be.

Should auditory perception really be a concern of the clinical optometrist? How could this *not* be? In order to encode and decode language with visual-motor and oculomotor skills, the child must learn how to sequence and decode phonemes and morphemes (the latter are not just individual sounds, but the smallest units of sound/speech that convey meaning: "bend", for instance, or the fragments "un-" or "-ing" that we can combine to make "unbending"). The child must be able to not only master the visual-motor skills to make well-formed letters fluidly, but also be able to *analyze the sounds* with ease to be able to determine which letters to make. Rosner's research[34] at the University of Pittsburgh in the late 1960's and early 1970's demonstrated that only two perceptual skills were needed in the classroom for reading and math: visual analytical skills and auditory analytical skills. Integrated, for sure, through general-motor activity, which he included in the remedial program.

The functional pathways in the brain, seen illustrated schematically in Fig. 2, are ordinarily enhanced by experience, but upon occasion, something interferes with the development of smooth, evenly integrated relationships. Sometimes it is the environmental lack of opportunity,[18, pp. 168-172] or illness, or sensory malfunction or pathology, or more and more commonly it seems, emotional.

Remedial techniques for these analytical skills are easily incorporated into a perceptual training program through activities like those of The Perceptual Skills Curriculum by Rosner[25] or the program called Auditory Discrimination in Depth, by the Lindamoods.[26]

Rhythmical movement training procedures, practiced for many years by many behavioral vision care teams are integrative and may be neurally catalytic when used in conjunction with all

visual, visual-perceptual, and auditory-perceptual therapy. Gross motor rhythmic training integrates large muscle/trunk skills, vestibular/proprioceptive skills, fine motor skills (ankle/toes), and auditory sequence/rhythm into this single activity.

The technique in **Appendix 1** should be well-known to most readers, whether or not they have discovered and used its remedial power. It is a very familiar technique done most easily on a rebounder-type trampoline It has been named "Mental Gymnastics" in our office. Its emphasis is on developing easy, automatic sequenced motor movements which are then combined with cognitive activities like Halapin cards, Kirschner Arrows, b-d-p-q charts, or math and spelling activities. Marching, clapping, choral speaking, singing, dancing, workout videos, and oddly enough, just listening to Mozart,[27] all have benefits in the domain of auditory processing. (Math skills as well, apparently, with the Mozart.)

5+2=1 REVISITED

Realize that figures 1 and 2 represent only the left hemisphere. There's another virtually identical lobe on the other side, with one important difference – it has a very different set of responsibilities in managing sensory input and output. Other sources can tell you more about the right/left brain differences. One can get swamped in the details. The treatment plan that is calculated to address the interweaving of data between the hemispheres and the "modules" of vision, speech, motor movement, kinesthesia, and cognitive planning in each hemisphere will invariably change the individual's interaction with her or his world.

Sensory integrative techniques in the therapy room will yield more rapid, more effective, longer lasting changes in the central nervous system. The treatment plan that limits its objectives to the peripheral visual system (the eye and extraocular muscles) will succeed eventually, but clinical history suggests that the changes are less pervasive.`

Five senses, plus two hemispheres, yields one person's very individualistic response. The behavioral/developmental visual care team is in the central position of being the most influential professionals in each individual's life. They have only to do their job *properly.*

Visually and otherwise, the word for the 21st century should be ***INTEGRATION*.**

SECTION TWO

WHAT RESEARCH CAN TELL THE VISUAL THERAPIST:
A Literature Overview

> *The very complex problem of explaining consciousness and mind is daunting, but no less an eminent light as Francis Crick (co-discover of DNA structure), and his colleague, Christof Koch, held that integrated, simultaneous high frequency firing of neurons in different parts of the brain may, as they mesh, generate consciousness.*

*Rodolfo Llinas has measured perfectly timed oscillations of cells in response to musical tone stimuli. He said that the signal says that "a whole lot of cells must be jumping up and down at the same time." (*Glimpses of the Mind*, Time, July 17, 1996)*

NEURAL PLASTICITY

There is a wholism and plasticity about the human body that is only just beginning to be appreciated. As this is written, news reports indicate that experiments have been recently performed that show that certain brain cells can be induced to become erythrocyte-producing (blood) cells. The environment surrounding the cells actually transforms the function. Also, there is little question now that adult human brains can add new cells. Researchers[28] are excited by the implications of this evidence, saying that it now removes the barriers to understanding neural plasticity. Sperry[29] has proposed that there is indeed a totality of neural cell action, a richly intercommunicating system that helps to explain the difficulties – impossibilities, really – of functions such as memory, perception, mind/behavior unity, voluntary control, and ultimately, *consciousness.*

This totality of brain function concept is new, but not really *that* new. Years ago, Adler[30] reported that Marina, in a set of experimental escapades, crossed monkeys' medial and lateral recti behind the globe and resutured them on to the eye, in each other's place. He also swapped places of the superior oblique and the lateral rectus in a second experiment, and in a third, switched the superior rectus and the lateral rectus. Within three or four days in each instance, the eye movements were either normal or nearly normal. Fearing,[31] a neural researcher, concluded that *these experiments demonstrated the inadequacy of the traditional theory that function was determined by the neural pathways*. (Emphasis added.) Adler wrote that Marina himself concluded that the conduction pathways for the control of the muscles had no predetermined function. Some of these experiments were repeated by Olmsted[32] who concluded that the cortex was indeed relatively plastic in its ability to partially or even completely change the character of its function.

Adler indicated that these observations plus others supported the conclusion that *it is function, not anatomical structure, that is represented in the motor cortex and that it responds to modification by means of plasticity*. (Emphasis added.) These experiments were performed over sixty years ago! It is surprising that their significance is being overlooked even to this day, for the implications to the practice of visual enhancement training are enormous.

THE BRAIN POWER OF LENSES AND PRISMS

Skeffington often said, "the value of lenses and prisms is neural, not optical". Each time an optometrist applies lenses and prisms for therapeutic application, (s)he is changing neural functioning and, based upon what is now being demonstrated in the research labs, we see that we are changing neural structure as well. But what is not new information, (and more important perhaps, than the recent research) may be the very old information uncovered by Marina, Fearing, Olmsted, and Adler, separately and in support of one another. It bears repeating: **it is actually *function* that is represented in the sensorimotor cortex, at the least, not anatomical structure and pathways.** This research gives further testimony, through indirect inference, that visual therapy operates upon the tissue of the

brain by modification of the function being trained, not by any peripheral effect in the orbits of the eye. Optical devices can then be better understood in the precise context that Skeff postulated: changing not the end organs and motor system, but changing the visual "posture" neurally.

REVELATIONS FROM NEW RESEARCH TECHNIQUES

The latest brain research supports multisensory visual therapy in exciting ways. For example, new techniques in neuroscience like the PET, fMRI, and "patch clamp" methods allow a look at living brains. The results from this research is giving a solid foundation to the clinical experiences that optometrists and their therapy assistants have seen over the decades. It especially validates the strategies visual therapists have used in integrating sensory modes: vision with auditory; touch; kinesthesia; and the right and left hemispheres' control of the body halves.

Through these new experimental methods, neuroscientists are able to analyze and dissect functional neural responses to a degree never before possible in living animals and humans. The impact of this upon neuroscience – and that includes developmental or neurodevelopmental optometry – is exciting and will either validate optometric rehabilitation strategies or will help us to modify current visual strategies to be able to get the best, most efficient results from our efforts to restore optimal visual functioning.

Neurobiological researchers[33] are confirming what clinicians have long since seen in therapeutic practice: the visual cortex does not consist of fixed receptive domains but, instead, what are dynamic fields of integration and association. It offers substantial support for the vision care team that uses a sensory integration approach in their treatment plan.

MULTISENSORY STIMULATION AUGMENTS RESPONSES

The very presence of smooth pursuit eye movements and stereo vision illustrate the deeply integrated nature of visuomotor function because both of them require huge amounts of sensory processing in multiple visual centers. It is futile, in the complexity of these tasks, to artificially assign strictly unique functions to any single component part of the visual system. Each part appears to be involved in many functions. Single neurons do not merely respond to single stimuli, resulting in single percepts, but each is impacted multiply, including the quality of the visual stimulus; eye position; and attentional effort. What appears to be a single response from a neuron is the culmination – a summation which then yields a multiplied response – of both perceptual and motor events. (Illustrated in Fig. 8) It is ambiguous until combined with many nerve cells, which add together into unique percepts and actions.[19-21]

FIG. 8
(Sensory inputs yield multiplied output)

Multisensory-designed visual therapy presents the opportunity for an amplified result, based upon these principles. Cells in the visual system are dynamic and have been demonstrated to be influenced by context, expectation, and long-term reconfiguring of the cortical network.[21] Research[14] also shows that auditory signals augment visual responses in the superior colliculus. Multimodal

training (visual, auditory, and kinesthesis) was superior to single-mode training in enhancing performance on kinesthetic distance matching.[15] There is a consistent enhancement of brain performance with integrated training.

BUILDING MIND MAPS

The integration of the senses is totally interactive: when an event occurs in one sensory system, the other senses become attuned to the spatial coordinates of that event automatically, covertly.[16,17] The very expectation of an event in a certain location has now been demonstrated to actually improve the judgments of the other sense modalities to that location. A multimodal, internal spatial map is being actively constructed and consulted. It is subconscious and contains data from visual, somatosensory, auditory, and vestibular inputs which are actively integrated in the posterior parietal cortex.[34,35] This develops the spatial reality with which the person operates and each person's mind map accuracy is dependent on the quality of the input. Feedback and feedforward then enable the individual to operate as adequately as he can, and sometimes when in the data is in error the result is the beginning of a visual problem. This is especially possible when either the stress of the environment, emotional stress, nutritional depletion or faulty learning of the neural systems force structural adaptations upon the end organs: in our area of concern, the eye and its motor systems.

Martin Sereno,[36] neuroscience researcher at University of California, San Diego, has been able to map the active processing of the brain while the subject is viewing a target, and then to unfold the map of the brain surface represented in the images. When comparing human maps to monkey cortex images, he found that foveal representation was much more widely represented. The human visual cortex, he concludes, has a preference for central information. Also, there is a connection with linguistic ability, he is finding, that is surprising. He suspects the connectional region to be in the visual cortex that lies beneath Wernicke's area. Other investigators[41] have discovered that the visual cortex itself is able to integrate information from much larger areas of the visual field than originally believed possible and with no apparent limitation by age. The importance of accurate foveal representation and the vast extent of cortex that it covers, verified by cortical mapping techniques, is not that surprising on one hand, but its apparent link to language *is*.[36]

Our operational mind maps are large[37], comprehensive and continually being modified throughout life.[38] The individual's ability to navigate his or her world physically, cognitively, and linguistically is dependent on the smooth integration of the different modules of sensorimotor functioning. The visual therapist is able to address these through knowledgeable design of the treatment plan.

ENVIRONMENT AND BEHAVIOR MODIFIES STRUCTURE

The hippocampus, which is involved in learning and memory formation, may be physically susceptible to the damage of post-traumatic stress disorder. Emotional, physical, and sexual distress can have marked demonstrable physical effect on the brain across time.[39-41] The amount of damage that will occur and the sum of the effects is probably regulated by genetic resilience. Our emotional environment can alter learning and behavior.

Rosenzweig, et al,[42] in their study of enriched environments upon rat brains, found that the rats who were raised in socially and activity-enriched cages had brains that were heavier, much more dense than their controls. Diamond, one of the co-researchers, also allowed that wild rats had the heaviest brains of all. The types of socialization and experiences that were engaged by the rats affected the density of neurons and neuroganglia in some regions of the callosum, cortex and hippocampal areas. These changes occurred no matter how old the rats were. Other experiments[43] have replicated the changes, done with rats who were exposed to maze learning versus less complex environments. These latter experiments are of more direct relevance to optometrists and educators.

We have known for over 500 years that the brain "pumps behavior", but the understanding that behavior impacts the brain only dates back some forty years. This concept of behavior includes the processing of perceptual stimuli and the reprocessing of response effects.[44] This means that input modifies brain structure, which further modifies the response. This is the sum and substance of rehabilitation therapy of all types. It is, of course, the central dynamic of visual therapy. The brain has been treated as though it alone impacts behavior, but the exciting new direction in neuropsychological research is that behavior has durable impact on the brain.[9] This appears to support all the experiences of clinical optometric visual therapy over the decades.

On the negative side of stimulus modification of the brain, Freeman and Thibos[45] showed that uncorrected high astigmatism in childhood appears to permanently impair cortical response to visual patterns oriented to the blurred meridian. They speculated that the neural cells that process these patterns were changed. If we can generalize upon this principle, this may be hard evidence that the absence of adequate environmental stimulation (at least *visual* stimulation) has a permanent adverse effect on the brain.

DELIBERATE EEG CHANGES AFFECT READING

Licht and Bakker, et al[46] also showed electrophysiologically that at least some aspects of the reading task are handled by the right hemisphere at age six and then by the left hemisphere after age eight. Overdevelopment of one hemisphere or the other can be seen in certain types of dyslexic children. They did hemisphere-specific training on these dyslexics and demonstrated that between-hemisphere EEG differences could be therapeutically affected. Also, it was found that the magnitude of the changes tended to concentrate with the reading improvement. The more that left-hemispheric deficient children were "leftened", the better the reading – especially so. The electrical balance and integration of the hemispheres was being enhanced. In other clinical reports of measurable differences in the brain, Ludlam[47] recorded changes in alpha blocking ability with visual therapy, and Bowan[48] reported increases in Beta waves (which reflect alertness and cognition) corresponding to visual and cognitive shifts in one adult patient over only an eight week period using multisensory and hemispheric integration techniques.

It is quite probable that hemispheric balancing is an inherent aspect of rhythmical activities. When the Purdue Perceptual-Motor Survey was analyzed for predictive capacities of the subtests, the best general predictors for reading were found to be dynamic body balance and organization of spatial movements, and arithmetic grades predicted by rhythmic writing, with postural stability adding further to prediction of the arithmetic grade.[49] Getman[5] alluded to the same general processes in his writings.

INTEGRATION, EFFIGIES, METAPHORS AND LANGUAGE

As the brain converges the sensory inputs, the inputs build an effigy – a mental image, a thought. Most people are greatly unaware of this process except when the skill or aptitude has been lost and the mind can no longer attend to the world in a convergent fashion (e.g., vision assists auditory inputs in most people when attempting to recognize speech, and vision dysfunction can affect auditory processing because of this).[50] The different sensory inputs are synkinetically combined -- integrated. Neurologically speaking, "convergence", "attention", and "integration" are virtually synonymous terms.

Following this line of thinking, Sereno, as discussed in the *Discover* article[51], believes that the visual system is a major pathway to language. He believes that through saccades, visual scenes are scanned, which updates an internal effigy, a cognitive representational map of the world, so the individual can get around (a mind map). He holds that language performs the same function for the most part, though with one very important difference: through language, the representation being built can be dealt with in terms of the past and the future. Words and saccades may be highly similar, he says, because they assimilate the parts of each "scene" experienced by the individual. "Present" inputs must be compared, matched and differentiated from "past" inputs in order to create a correct mental picture. Sereno compares the process of language-to-pictures to the construction of a metaphor. Each process deals with concrete-to-abstract representation. One must realize that language doesn't just "translate" an experience, it actually *represents* experience in the neural system.[52]

CONCLUSION: WHAT DOES ALL THIS MEAN?

Skeffington, in proposing the four circles model of vision, knew that speech and audition were intimately integrated with vision. Earlier, I diagrammatically showed how vision and speech may intertwine with language becoming the emergent from the blending. Language builds the internal – and also temporal? – abstract representation of our external, spatial reality. Language can assume "future" and "past" qualities in a way that pure visual experience does not permit. Language, built from the integration of the multiple sensory inputs, then fills out the richness, the breadth, and the depth of our human experience. A visual problem always affects our inner language and *that* affects our outer language.

Understand, a visual problem is not ever simple. It is never "just a myope", "just a strab", or an "amblyope", or any other simplistic reduction of terms. A non-organic visual problem is always an operational problem: the integration of inputs combined with the length of time the organism must deal with that input and its quality. Our world as we know it is built from the integration, the melding of all our sensory data into a very individualized image – an *effigy* – of our reality. Ronchi[53] spoke more than fifty years ago of the *effigy* that the mind builds, clothing it with form and color, projecting it into space, and only then saying "I see". Neuroscientists have now neurally verified something like this process and identified the multisensory components and their interactions.[19,34,35] A person's perception of reality has the opportunity to change as we change the operation of the visual processing.

Visual therapy techniques that are designed to tap into multisensory inputs and reinforcement

appear to have advantage over those that do not. They clinically have been seen to be more dynamic in the remediation that occurs.

So what does this mean to the behavioral vision care team, the optometrist and the visual therapy assistant, in particular? Well…sensory integration is intimate to all cognitive processes. As we approach the visual system as an integrated process, wholistically, the therapists will inevitably change the brain, changing the person.

The vision care team will be treating the person *"properly".*

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APPENDIX 1

MENTAL GYMNASTICS

(Bilateral Integration - Cognitive Loading)

WHY - Research at the University of Illinois in 1990 showed that simple mental tasks are best handled by using one hemisphere of the brain at a time, and that complex mental tasks were best handled by the use of both hemispheres of the brain simultaneously. School work requires complex thinking.

The smooth usage of both sides of the brain together is an acquired skill, in large part. We become more adept at interweaving their activity as neuromaturation occurs and spatial-motor skills become refined. Unfortunately, our "modern" society and sedentary lifestyles have de-emphasized pure motor skills activities and have tended to replace those activities with adult, *thought-oriented* activities in their place. This appears to be a totally inadequate preparation for thinking for a significant sector of our school-age population (estimated at from 15-30%).

The balance of the school-age children could benefit from these activities, as well, it is believed.

And so, we have a growing number of children who are taught to think, perhaps also taught to do, but who have had less than adequate opportunities to think and do simultaneously. The performance of any one skill degrades when an additional sensory or motor stimulus is added to input, in a phenomenon known as cognitive loading. (The old story about people so uncoordinated that they can't walk and chew gum at the same time illustrates the folk awareness of this.)

This new activity first builds bilateral integration and then adds cognitive loading by requiring mental problem solving, training the automaticity of both. The inclusion of this technique in training for over twenty years has been shown to be catalytic, doubling the rate of progress, cutting in half the length of therapy in virtually all cases, with only a few exceptions.

WHEN - This activity should take about five minutes, the child's endurance providing, for each daily session. This activity is so important as to require priority over any other technique - please do not omit it, and please do it even though no other may be performed.

EQUIPMENT - The ideal piece of equipment is a "rebounder" - type trampoline. Many families have one, many others can borrow one for a few months from a relative or a neighbor. They are often found at garage sales and/or flea markets for a few dollars. Brand new ones are available for $15.00 - $50.00 at discount houses. In lieu of a tramp, an old cushion or a folded Orlon blanket, or even a couple thick shaggy rug samples available for under a dollar at a flooring center will suffice. The object is to reduce ankle impact force with the floor, if at all possible. It may be done on the floor itself, as a last possibility.

HOW - the purpose of tapping the four rhythms is to assure that the child can generate them from the auditory sections of the brain. They should be smooth, even, steady - missing no beats as if a metronome were beating (but don't use one, it is too demanding at this point). Watch for signs of "segmenting" of the production (a conscious switch from right to left hemispheres of the brain ["tap-**TAP** -- tap-**TAP**" is generally heard]).

The training uses tapping to train the rhythm in the brain, the actual value comes from hopping, which is gradually added in as noted.

A. TAP 1 and 1 - Goal: slow, steady, even and automatic production. ("TAP-TAP-TAP-TAP", etc.)

B. TAP 2 and 2 - GOAL: as above. You may now start hopping 1 and 1 as part of the training session.

C. TAP 1 and 2 - Goal: as above. Watch for and avoid "tap-tap-TAP -- tap-tap-TAP" - a segmentation with a rest included. There should be no emphasis on any of the beats. Try both the right and left hands as the "1" beat - then use whichever way seems easiest as the mark for this step. Also, start 2 and 2 hopping if skills allow - 1 and 1 hopping must appear very automatic before you do, however.

D. TAP 2 and 1 - Goal: as in C. Now use the opposite hand from C. as the "1" beat. Also, start 1 and 2 hopping if ready for it, testing as you did the hands in C. for best performance. If not ready, continue 2 and 2.

E. ALTERNATE TAPPING - Switch C. and D. upon command. Also, start hopping 2 and 1 hopping if 2 and 2 and 1 and 2 patterns are automatic by now.

F. HOPPING - Work on 1 and 2 and 2 and 1 patterns until your child is able to switch easily back and forth (with the loss of no more than one beat) upon your command.

[This activity integrates at least five sensory and motor skills: Visual (for balance); Auditory/temporal (the rhythm); Gross Motor; Fine Motor (ankles and toes used in balancing); and Vestibular (balancing/bodily coordinates).]

Automaticity needs to be stressed, so that the production of the rhythm appears virtually effortless. When adding to the tapping routine, spend about half of the time on the hopping - about two or three minutes of the five minute total.

COGNITIVE LOADING - After all the rhythms can be easily produced (or upon the instruction of your therapist) these activities are added to the hopping:

A. FAMILIAR TERMS - have the child repeat all the family names that he/she can, known addresses, telephone numbers, the alphabet, nursery rhymes, give directions on how to drive to school, to church, how to get to different rooms in the house from the front and back doors, describe pets, etc. - all while maintaining the rhythm. Stress that it is more important to keep the rhythm going than to keep talking - and not to stop hopping while thinking of the answers. Extra demand is added by having your child do these things in reverse order to the extent that he/she can -- but not the alphabet -- yet. Practicing math facts is also good, but this is not the time to teach the math facts. Practice with all the rhythms (hopping only - tapping will no longer be needed).

B. FAMILIAR CONCEPTS - count by ones to 100 (less for younger children), counting by twos, then by fives, counting by odd numbers, then threes, fours, sevens. These demands can be reversed at any time - but at all times, tailor the task to assure success with a bit of "reaching". We don't want to expose the child to repeated failure - there's enough of that already in your child's life. Use the alphabet in sections forward and backward (your child shouldn't have to recite from a to e to give you f through m) - only do them backwards in three, four, or five letter segments at first - whatever your student can succeed with.

C. UNFAMILIAR CONCEPTS - spelling words backwards, counting by adding and then subtracting sums (i.e., add 3, then subtract 2 from each answer starting with 1 - or another, different starting number). Vary the sequences. Also, present math facts in unique ways: "How many 4's are there in 24?" or, "How many times can I subtract 3 from 27?", etc.

D. OTHER - You may also be given a chart of arrows to have the child recite the directions of while hopping and pointing with their arms in a whole-body, exaggerated way. This helps to embed a sense of directionality in the child's mind and helps to minimize the tendency to visually scan words backwards (word reversals).

For those with oculomotor problems, the following will be recommended: imagine cards at the four corners of the wall in front of you at the floor and ceiling. While hopping 2 and 2, look to each of the corners for the two beats of each foot's hops. Continue for at least ten times around. If this is easy and automatic, switch to the uneven hops, using a three count for each number. (1 and 1 is done after these have been mastered, using a two count: R - L, SHIFT, R - L, SHIFT, ETC.) NOTE: You do not need to do this procedure unless directed.

CONCLUSION - The object of Mental Gymnastics is to develop an internalized pattern of being able to think and do simultaneously with motor production. Clinically, this technique has proven both highly effective and expedient. It gives us the clinical impression of enabling the child to "multitask" his daily routine when he hasn't been able to previously . This affects the rate of therapy and reflects itself in the child's daily work and grades.

Enjoy!

MDB 3/98

References

1. Fixot RS; Am J Ophthal, 1957 Aug.
2. Skeffington AM; Clinical optomtery. Post doctoral courses, Optom Extension Prog. Santa Ana, Calif. 1928-1969.
3. Harmon DB; Notes on a dynamic theory of vision. 1958.
4. Renshaw S; Psychological optics. Post doctoral courses, Optom Extension Prog. Santa Ana, Calif. 1943-65.
5. Getman GN; Vision: its role and integration in learning processes. J Learn Dis 1981 Dec; 14(10):577-80.
6. Kraskin R; Visual training in action. Post doctoral courses, Optom Extension Prog. Santa Ana, Calif. 1965-68.
7. Gesell A, Ilg FL, Bullis GE; Vision: its development in infant and child. Harper and Row:1949. Reprinted: 1998 Optom Extension Prog. Santa Ana, Calif.
8. Shatz C; cited by: Nash M, in Fertile Minds, Time, 3 Feb 1997.
9. Gazzaniga MS; The split brain revisited, Sci. Am., July 1998.
10. Healy JM; Your child's growing mind, Main Street Books Ed., Doubleday, NY, 1994.
11. Koffmehl W; linguist and remedial educator, personal communication, 1998.
12. Berry MF; Language disorders of children, Appleton-Century-Crofts, NY, 1969.
13. Gilbert CD; Horizontal integration and cortical dynamics. Neuron 1992, Jul; 9(1):1-13.
14. Peck CK; Visual-auditory interactions in cat superior colliculus: their role in the control of gaze, Brain Res. 1987 Sept 8; 420(1): 162-6.
15. Crabtree DA Crabtree MP; Transfer of sensory-integration training, Percept Mot Skills 1987 Apr; 64(2): 643-9.
16. Driver J, Spence C; Cross-modal links in spatial attention. Philos Trans. R. Soc. Lond. B. Biol Sci, 1998, Aug. 29; 353 (1373): 1319-31.
17. Driver J, Spence C; Crossmodal attention, Curr Opin Neurobiol 1998 Apr; 8(2): 245-53.
18. Healy JM; Endangered Minds: Why children don't think and what we can do about it, A Touchstone Book, Simon and Schuster, New York, 1990.
19. Wallace MT, Meredith MA, Stein BE; Multisensory integration in the superior colliculus of the alert cat, J Neurophysiol 1998 Aug; 80(2): 1006-10.
20. Douglas RJ, Martin KA, Nelson JC; The neurobiology of primate vision, Baillieres Clin Neurol 1993 Aug; 2(2): 191-225.
21. Meredith MA, Stein BE; Spatial determinants of multisensory integration in cat superior colliculus neurons, J Neurophysiol 1996 May; 75(5): 1843-57.
22. Bowan MD; A perceptual-motor model of language, J. Behav. Optom (in rewrite).
23. Flax N; The four circles of vision revisited, presentation at the 39th Skeffington Invitational Symposium, Wash DC, Jan 21-13, 1995.
24. Rosner J; An Individualized Perceptual Skills Curriculum, , Publication 1972/7, Learning Research and Development Center, U. of Pittsburgh, Pittsburgh, PA.
25. Rosner J; The Perceptual Skills Curriculum ,Walker Books, NY, NY 1973.
26. Lindamood C, Lindamood P; Auditory Discrimination in Depth, Developmental Learning Materials, DLM Teaching Resources, 1975.
27. Rauscher FH, Shaw GL, Ky KN; Listening to Mozart enhances spatial-temporal reasoning: toward a neurophysiological basis, Neuroscience Letters, 185(1995) 44-47.
28. Travis J; Adult Human Brains add new cells, Science News, Vol. 154, Oct 31, 1998.
29. Sperry RW; Cited in: Doty RW; The five mysteries of the mind, and their consequences, Neuropsychologia, 1998 Oct; 36(10): 1069-76.
30. Adler FH; Physiology of the eye: 3rd Ed., 1959, C.V. Mosby, St. Louis.
31. Fearing F; Reflex action, 1930, Williams and Wilkins Co., Baltimore.
32. Olmsted J, Marguti M, Anagasta K; Adaptation to transposition of eye muscles; Am J Physiol, 116(245) 1936.
33. Fregnac Y, Bringuier V, Chavane F, Glaeser L, Lorenceau J; An intracellular study of space and time representation in primary visual cortical receptive fields. J Physiol Paris 1996; 90(3-4): 189-97.
34. Anderson, RA; Multimodal integration for the representation of space in the posterior parietal cortex, Philos Trans. R. Soc. Lond. B. Biol Sci, 1997, Oct; 29; 352 (1360): 1421-8.
35. Ladavas E, Pavani F; Neuropsychological evidence of the functional integration of visual, auditory and proprioceptive spatial maps, Neuroreport 1998 Apr; 9(6): 1195-200.
36. Sereno M; quoted in, Gutin JC; A brain that talks, Discover, June 1996.
37. Bower, B; Map unfolds for brain's vision area, Science News 146 (May 13 1995, p. 295).
38. Gilbert CD, Das A, Ito M, Kapadia M, Westheimer G; Spatial integration and cortical dynamics, Proc Natl Acad Sci USA 1996 Jan 23; 93(2): 628-33.

39. Peterson I; Child sex abuse leaves mark on brain, Science News, Vol. 147 June 7, 1995.
40. Sapolsky RM; Stress, glucocorticoids and damage to the nervous system: the current state of confusion, Stress 1996 Jul; 1(1): 1-19.
41. Friston, KJ, Buechel C, Fink GR, Morris J, Rolls E, Dolan RJ; Psychophysiological and modulatory interactions in neuroimaging, Neuroimage 1997 Oct; 6(3): 218-29.
42. Rosenzweig MR, Bennet, EL, Diamond MC; Brain changes in response to experience, Sci. Am. 1972: 226:22-30.
43. Rosenzweig, MR; Responsiveness of brain size to individual experience: behavioral and evolutionary implications; in: Development and evolution of brain size, Hahn ME, Jensen C, Dudek BC (Eds.); (pp. 263-294) 1979, Academic Press, NY.
44. Bakker, DJ; The brain as a dependent variable; J. Clin. Neuropsych. 1984 6(1):1-16.
45. Freeman RD, Thibos LN; Electrophysiological evidence that abnormal early visual experiences modify the human brain, Science 1973; (180):987-989.
46. Licht R, Bakker DJ, Kok A, Bouma A; Hemispheric asymmetry and learning to read: a longitudinal ERP study. Paper presented at the meeting of the International Neuropsychological Society, Lisbon, Portugal, June 1983.
47. Ludlam WM; Visual training, the alpha activation cycle and reading. J Am Opt Assoc 1979.
48. Bowan MD; Preventing refractive error: what is a doctor to DO? Proceedings of the 3rd International Congress of Behavioral Optometry, May 1-4, 1998, Washington, DC, OEP, Santa Ana, CA.
49. Dunsing JD; Perceptual-motor factors in the development of school readiness: an analysis of the Purdue Perceptual-Motor Survey, Am J Optom Arch Amer Acad Optom, 1969 Oct.
50. Lemonick MD; Glimpses of the mind, Time 1995 July 17.
51. Caplan D; Language and the brain, Harvard Mahoney Neuroscience Institute Letter, Fall 1995, Vol 4(4) (http://www.med.harvard.edu/publications/On_The_Brain/Volume4/Number4/F95L).
52. Gutin JC; A brain that talks, Discover, June 1996.
53. Ronchi V. Optics, the science of vision. (Trans. E. Rosen) 1957, New York: New York University Press.

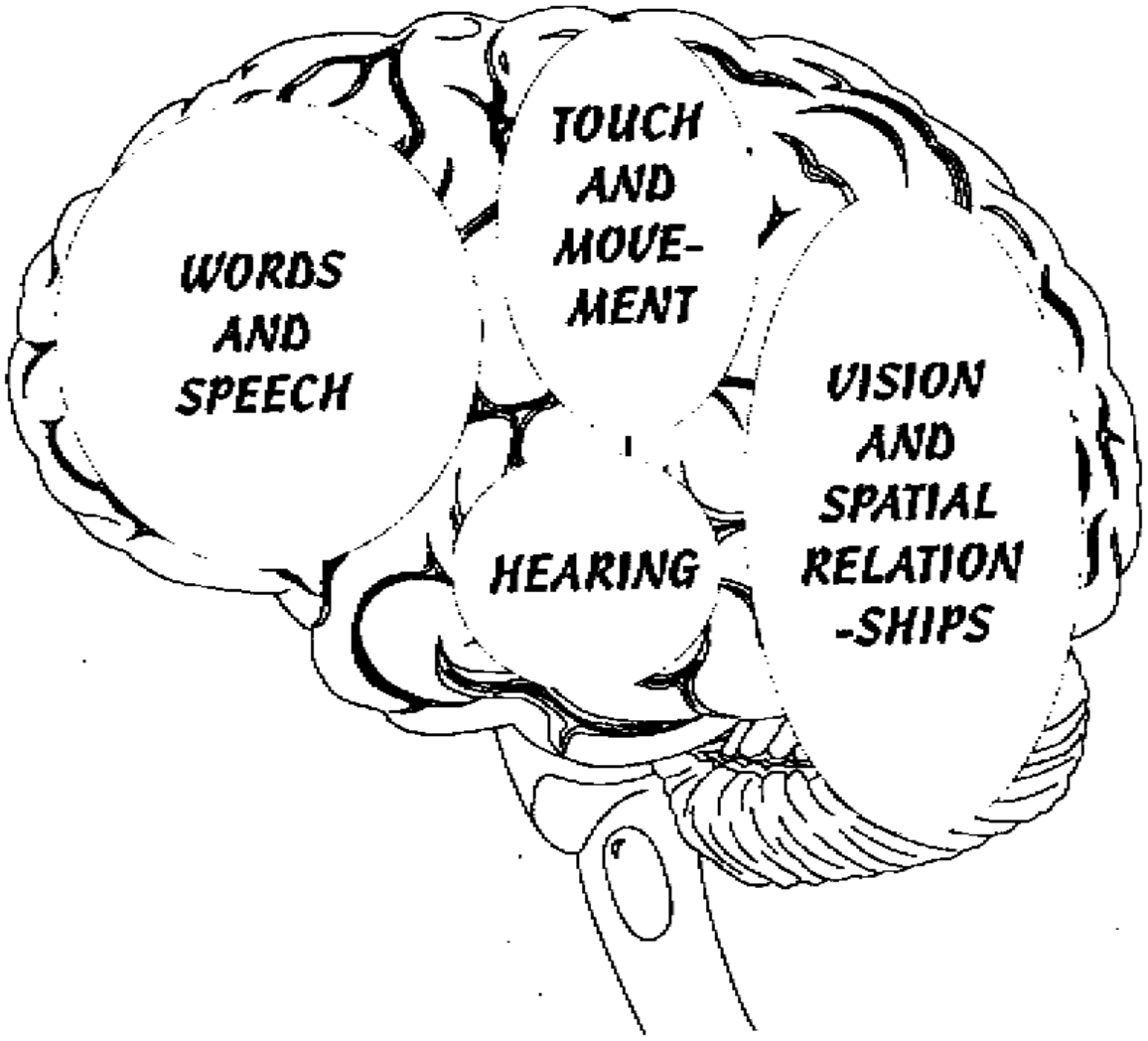

Figure 1. Brain with functional areas.

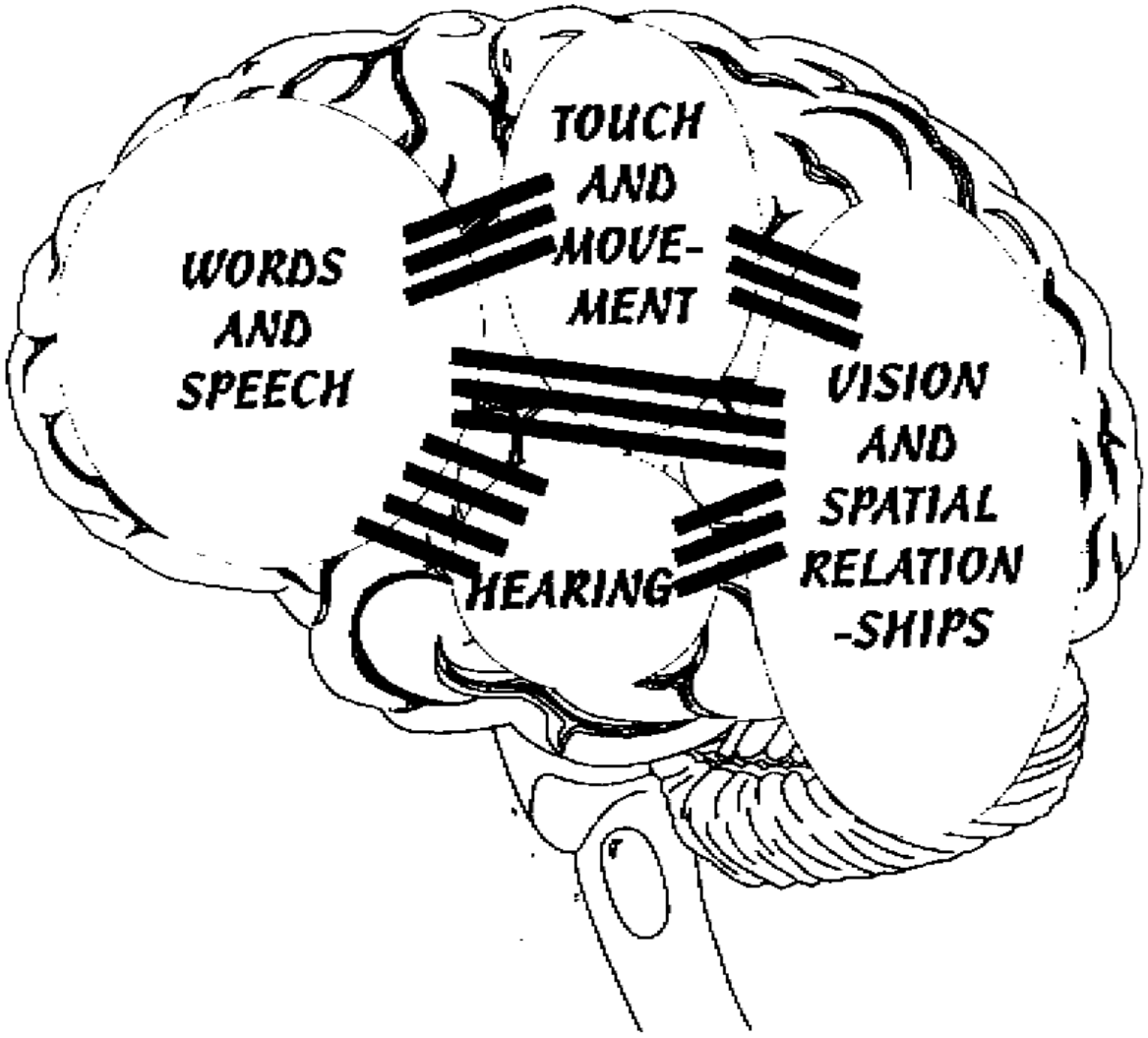

Figure 2. Tracks are added.

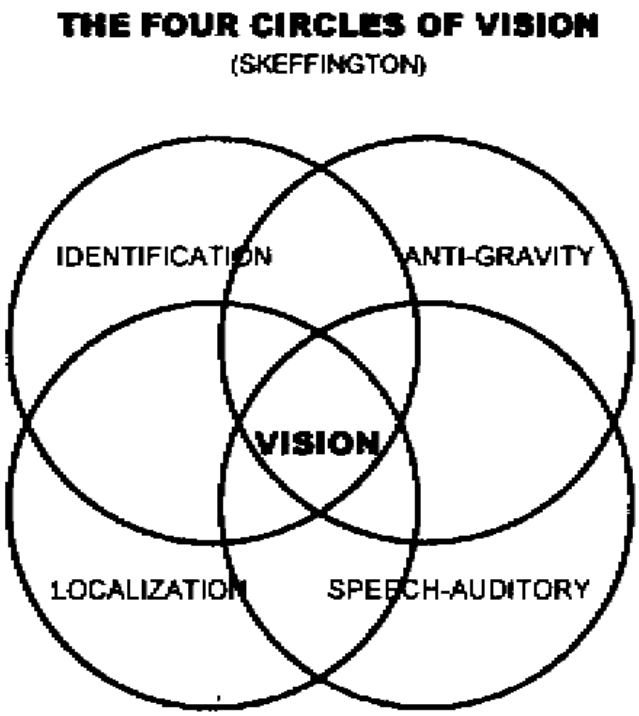

Figure 3. Skeffington's Four Circles of Vision.

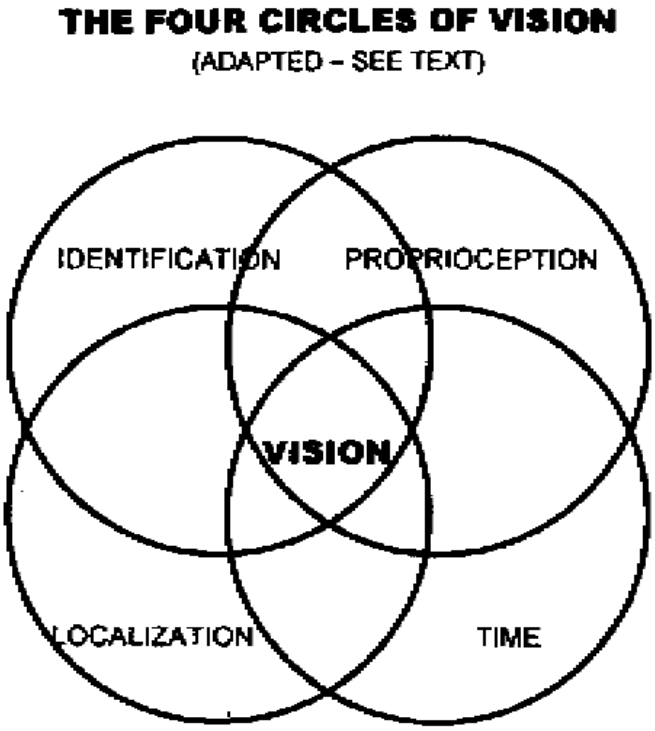

Figure 4. Bowan's Adapted Four Circles of Vision.

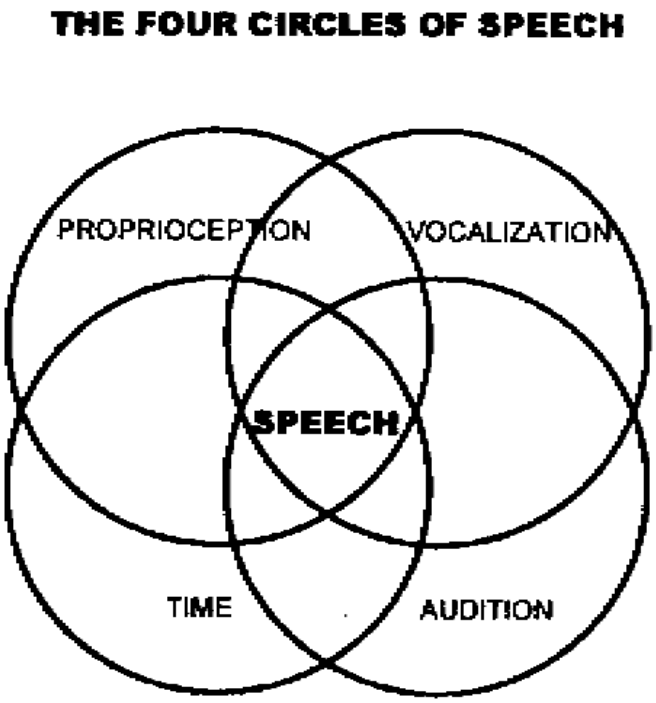

Figure 5. Bowan's Four Circles of Speech.

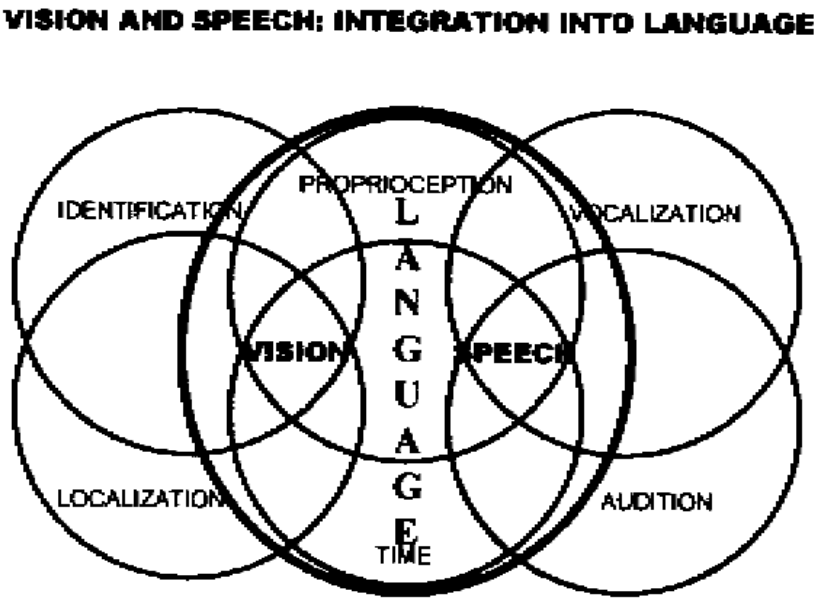

Figure 6. Six Circles of Language.

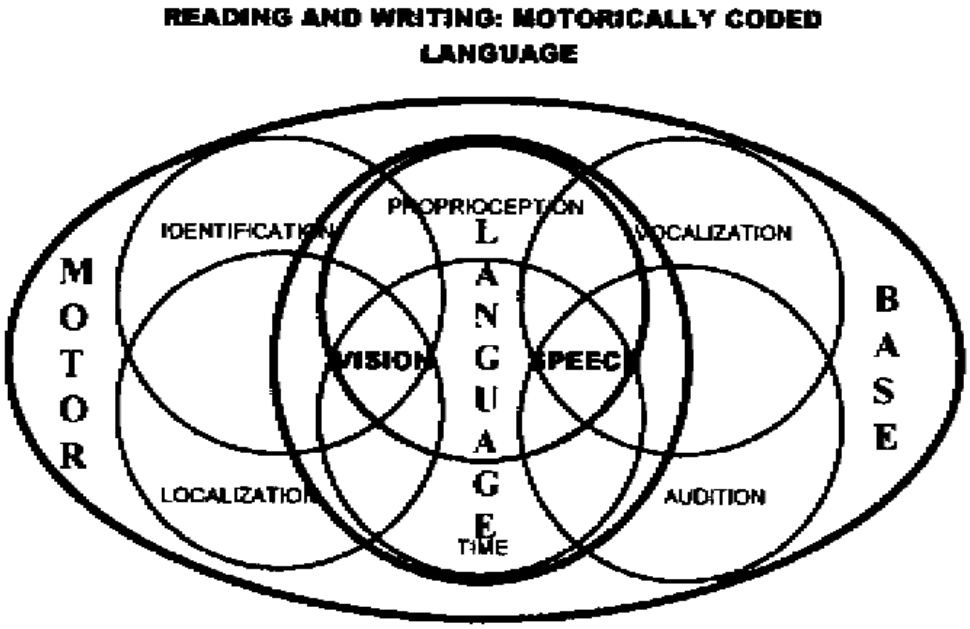

Figure 7. Seven Circles of Reading.

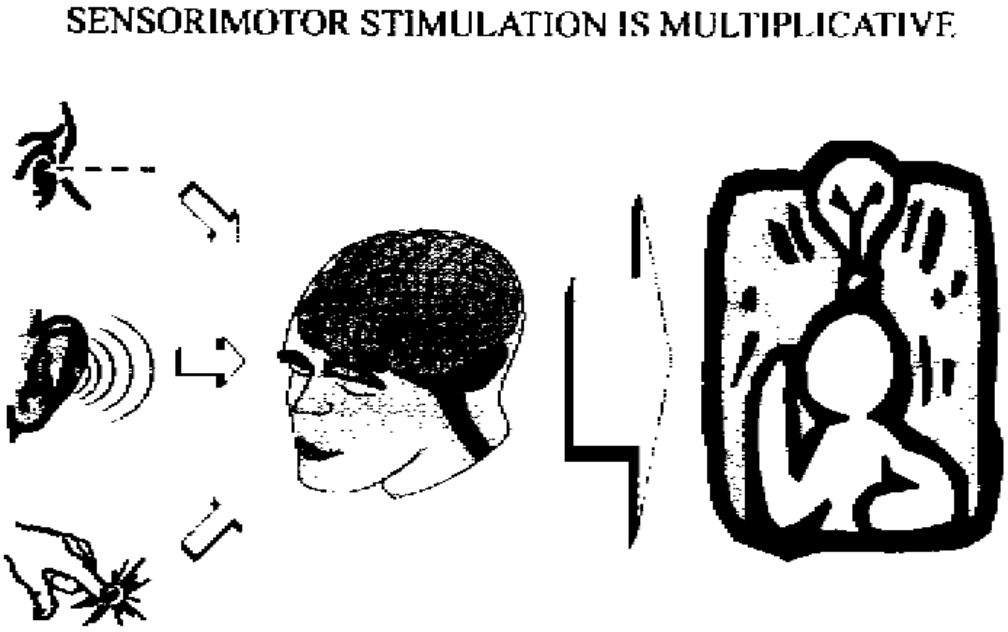

Figure 8. Sensory inputs yield multiplied output.