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An Historical Commentary on the Physiological Effects of Music: Tomatis, Mozart and Neuropsychology

BILLIE M. THOMPSON, Ph.D.[1]
SUSAN R. ANDREWS, Ph.D.[2]
[1]*Sound* Listening & Learning Center
[2]*Listening* and Leaming Center

Abstract–This article provides an overview of the theoretical underpinnings of the Tomatis Method, along with a commentary on other forms of sound/music training and the need for research. **A** public debate was sparked over the "Mozart Effect." This debate has turned out to be unfortunate because the real story is being missed.

The real story starts with Alfred Tomatis, M.D., scientist and innovator. Dr. Tomatis was the first to develop a technique using modified music to stimulate the rich interconnections between the ear and the nervous system to integrate aspects of human development and behavior. The originating theories behind the Tomatis Method are reviewed to describe the ear's clear connection to the brain and the nervous system. The "neuropsychology of sound training" describes how and what the Tomatis Method effects.

Since Dr. Tomatis opened this field in the mid 20th century, no fewer than a dozen offshoot and related systems of training have been developed. Though each new system of treatment makes claims of effectiveness, no research exists to substantiate their claims. Rather, each simplified system bases its "right to exist and advertise" on the claimed relationship to Tomatis and his complex Method. Research is desperately needed in this area.

The 50 years of clinical experience and anecdotal evidence amassed by Tomatis show that sound stimulation can provide a valuable remediation and developmental training tool for people of all ages. Offshoot systems have watered down the Tomatis Method without research to guide the decisions of simplifying the techniques and equipment.

Introduction

MUSIC HAS BEEN used for healing and stimulating emotions for centuries. The Greeks at Asclepius placed an ill person in the center of the ampitheater and used specific voices to heal that individual. Much later than the Greek choruses, new instruments, and what has come to be called classical music, emerged to entertain through live performances by individuals, small groups, and entire orchestras. Some classical composers and performers rose to the top of public acclaim in their time. Their work has continued to stimulate us down through the centuries in versions much as the composers conceived of them, and also in ways modified to accomplish particular purposes.

An exciting public debate has arisen over the music of Mozart, mostly due to the books of Campbell (The Mozart *Effect*™, 1997) and Shaw (Keeping Mozart in Mind, 1999). The

Address for correspondence: Sound Listening & Learning Center, 301 E. Bethany Home, Suite A–107, Phoenix, AZ 85012; E-mail: bthompson@soundlistening.com

debate concerns whether or not there is such a phenomenon as a "Mozart Effect." The public is still trying to understand what the Mozart Effect is; in the process, an entire important area of research is being oversimplified. The public is in danger once again of "throwing the baby out with the bath water."

Two distinct lines of research would provide answers: (1) research to investigate the transient effects of listening to a few minutes of Mozart's music on a few highly specialized instruments designed to measure areas of higher cognition and (2) research to carefully determine the lasting effects of intensive hours of listening to Mozart and other forms of music through specially designed equipment that enhances the effects of the auditory stimulation on the neurological system. Unfortunately, only the former is being pursued actively and the second is being lost or confused as the "same thing" as the first.

The oversimplification results from a public interest that arose following the publication of the pilot study from the University of California-Irvine (Rauscher et al., 1993). This seminal study concluded that 3–year-olds, who listened to 15 minutes of Mozart prior to taking several subtests from an intelligence test, showed enhanced specific spatial reasoning skills.

Many attempts to reproduce this "effect" used different methodologies and operationally defined the variables in dissimilar ways, yielding different and conflicting findings. This has lead to a controversy as to whether or not the "Mozart Effect" exists.

Subsequently, Don Campbell introduced his popular book, *The Mozart Effect*™ (1997), in which he described a much broader field of effect of music on humans. Campbell started by describing his own efforts to use music to heal himself of a tumor by combining music and toning with meditation. He then introduced Alfred Tomatis and his work before broadening the text to include the general power of music to enhance child and adult learning and health. The use of the term, "the Mozart Effect," at this point became confused in the public mind. The term now includes everything from a laboratory experiment in which a child listens to 15 minutes of music to the intensive training with very specialized equipment developed by Tomatis to listening to classical music in the privacy of one's home. The confusion is unfortunate because a focus on an experimental paradigm of 15 minutes of stimulation begs the question and does not reveal the integrating neurological response elicited from specialized listening training, such as the Tomatis Method.

The Real Story: The Tomatis Story

The real story starts with Alfred A. Tomatis, M.D., scientist and innovator. Dr. Tomatis was the first to recognize the role of the ear in the production of the voice. He discovered the far reaching effects of sound stimulation, used over a sufficient amount of time, to condition one's ear to improve discrimination between and analysis of the sounds of music and voice. He developed a method specifically to stimulate the rich interconnections between the ear and the nervous system. His method proved to impact on and integrate aspects of human development and behavior so much that Dr. Tomatis came to see human life through the focal point of the ear.

Tomatis' first book, published in French in 1963 as *L'Oreille et la langage* and in English in 1996 as *The Ear and Language*, introduced his philosophy and initial research. Only three of his 15 books were translated into English, of which only *The Ear and Language* is still in print. He published his autobiography in French in 1979 as *L'Oreille et la vie* and in English in 1991 as *The Conscious Ear*. *Education and Dyslexia* is the third book.

The autobiography depicts a life of research that led to several significant discoveries. Though Tomatis retired in 1995, his Method continues to evolve and to offer solutions in many human arenas: educational, developmental, personal growth, language, musical, and rehabilitative conditions.

The story of how Tomatis made his discoveries and developed what ultimately became known as the Tomatis Method is told in *The* Conscious *Ear*. Tomatis identified several "laws" governing the ear and voice and its effects on our behavior and abilities. The principal law with its two corollaries form the scientific basis for the Method and initially drove the fundamental engineering concept behind the development of Tomatis' major invention, the Electronic Ear (EE). The EE was developed in order to assist the human ear to establish or re-establish its full potential. Dr. Tomatis developed and received seven U.S. patents for components of the EE.

Briefly, the "Tomatis Effect" was discovered early in Tomatis' work when he worked simultaneously with two diverse groups of people: professional singers who had difficulty producing sounds they once had easily produced and ammunition factory workers with hearing loss (Tomatis, 1977, 1991). By comparing the audiograms and spectrographs of the two groups, Tomatis discovered the first law, that "A person can only reproduce vocally what he is capable of hearing."

Tomatis showed that the two organs, ear and larynx, are part of the same neurological loop. Therefore, changes in the ear will immediately affect the voice, and vice versa. Both the quality of voice and speech fluency are largely affected by the quality of the ear's listening. The French Academies of Medicine and Science documented the validity of this theory at the Sorbonne in 1957 (le Gall, 1961). Tomatis' first corollary concerns restoring auditory capability: if the defective ear can be "retuned" or re-educated to hear missing or faulty frequencies, then these are instantly and unconsciously restored in the vocal emission.

His second corollary concerns self-listening: controlled auditory stimulation can alter one's self-listening and phonation. If one listens to one's own voice heard with a good quality, and conditions one's ear sufficiently in this manner, the changes will be maintained.

He positioned the "listening function" as a major process, affecting voice, language, rhythm and coordination, motivation, and learning abilities. He distinguished hearing, the passive reception of sound, from listening, which is the active, motivated tuning in to what you want to hear and tuning out what you do not want to hear. One can have good hearing and still have poor listening.

Tomatis' Conception of Sound Analysis via Bone and Air Conduction

Tomatis proposed (1974a, 1974b) a different view of the ear than Von Békésy (1960), who was awarded a Nobel prize for his theory. Tomatis observed that too much distance separates the incus and stapes, and the presence of collagen there prevents the occurrence of sound with a human fidelity capability. Instead of conducting sound, Tomatis theorized that the ossicles protect the inner ear from damage by dampening the tympanic membrane vibratory energy via a feedback loop from the endolymph. The endolymph buffers the shearing potential of the vibrational force to protect the Corti cells. Bone conduction occurs even when the ossicles are removed, with a resultant flaccid contact between the tympanic membrane and tympanic sulcus causing air conduction hearing loss.

Tomatis claimed bone conduction is the major route of sound conduction to the inner ear. He observed that the endochondral capsule is the only place in the human body where primitive bone, which developed from fetal cartilage, persists unchanged (no resorption) from before birth until after death. Thus, this static medium is the ideal conductor for vibratory energy. The cells of Corti are end organs rather than sensory cells, such that they play a role in cochlear mechanics. The stapedius muscle controls the stapes and regulates high-frequency audition and never rests; it is the only muscle of the human body to do this (Tomatis, 1974b).

Brief Summary of the Tomatis Method and the Electronic Ear

The Tomatis Method is provided over an intense but relatively short time span. A description of the Method and a typical program has been presented in detail in several publications (Thompson, 1993a; Thompson, 1993b; Thompson and Andrews, 1999). In general, one listens from one to two hours daily during intensives that are separated by breaks for integration of changes. For some types of training, 30 to 60 hours are sufficient. For others with developmental and/or rehabilitative needs, the training can continue until goals have been achieved. Periodic consultations and assessments are an integral part of the Tomatis Method. An Initial Assessment and reassessments to determine progress and the next phase of the program support the person to learn at an optimum rate.

The EE delivers the sound stimulation through special earphones that conduct both bone and air conduction. Specially-formulated audio-tapes are used for the music input. They are not commercially available to the public. The importance of the EE and the related equipment is that Tomatis designed them in accordance with his theories of (1) how the ear works, (2) how the ear best influences the neurological system, and (3) the primary functions of the ear.

At least four aspects of how the EE operates are important to an explanation of the underlying theory. First, Tomatis built into the EE a set of filters to regulate sound so that the information is altered or modified to focus evenly on the specific frequency band range of a good functioning ear in order to suppress distortion. Besides settings to extend the range of listening and speech as wide as possible, the filters can be set to improve reception for a particular language and to develop a musical ear, which he considered to be an ideal listening ear.

Second, an electronic gating mechanism enables the ear to attune itself automatically and spontaneously for listening. Stimulation of the middle ear is achieved by the alternating passage of sound from one channel, which is set to relax the muscles, to another channel, set to tense or focus the muscles. Repetition of the gating action over time conditions the ear to operate more efficiently to perceive and analyze sound properly.

Third, the EE provides a control to vary the balance of sound between the right and left ears. The most direct route to the speech center in the left side of the brain is through a dominant right ear. Sound intensity fed via earphones to the left ear is progressively reduced so as to prepare the right ear to become the lead ear for listening and audio-vocal self-monitoring.

Finally, the timing delay of sound reception between the bone and air conduction can be changed to slow down the processing of information internally and to awaken the individual to attend to incoming information. The delay is gradually changed to support a more rapid response to incoming information.

Theoretical Foundations to the Tomatis Method

Tomatis recognized that the whole of the nervous system is intimately related to the auditory apparatus. The ear is important in the regulation of balance, posture, and the movement of our body. Oddly, the ear helps regulate eye movements and spatial awareness, and, of course, the ear is essential to our ability to use language. Tomatis' work on the ontogenesis of listening and the auditory system combined important elements of many fields (Gilmor, 1989). Tomatis found his work related to fetal audition to be most enticing. He says his own premature birth caused him to search for what he had missed (Tomatis, 1977, 1991). He was among the first to postulate that the fetus hears (Tomatis, 1963)—common knowledge now (Eisenberg, 1976; Verny, 1981; Chamberlain, 1983; Spence & DeCasper, 1986), but not thirty years ago.

Listening actually begins in the womb. The ear and the neuron tracks between the ears and the brain are already fully developed and operational in the fifth month of pregnancy (Tomatis, 1987). If human auditory development is similar to that of animals, then research (Abrams et al., 1987) supports Tomatis' contention that it is the ear that plays a vital role in developing human potential. Abrams found that, at least for fetal sheep, normal growth and maturation of the brain depends on an intact auditory system.

What is the fetus listening to, anyway? Certainly to the sounds of the mother's body, and more importantly, to her voice. For decades preceding other researchers, Tomatis contended that the voice of the mother speaking and singing plays a key role in the child's language acquisition and development and in social communication skill development (Tomatis, 1963). His research indicated that the fetus listens to the highly filtered mother's voice and that high frequency sounds thereof are received and stimulate the brain of the fetus. His theory has changed over the years regarding the exact mechanism by which this is done. Auditory and vestibular pathways in the brain are extensive, possibly found in 85 percent to 90 percent of the brain.

Querleu et al. (1989) reports on research about interuterine sound. Though most research using interuterine microphones shows that the higher frequency sounds are attenuated inside the uterus, new amplication techniques have indicated that the attenuation of sounds above 2,000 Hz have been overestimated.

The higher frequency components of the musical triangle, generated directly with an intensity of 70 to 80 dB, emerge from 3,800 to above 18,000 Hz, with an attenuation ranging from 20 to 40 dB linear. Transmission of high frequencies to the uterine cavity is thus possible, yet their audibility was not demonstrated in this experiment (p. 412–413). Using non-linear response-curve microphones, Querleu et al. (1989) found that "the spectra of synthetic vowels emitted ex utero and recorded in utero emerge up above 5,000 Hz. This finding suggests that high speech frequencies would be transmitted" (p. 413).

Other research from Querleu et al. (1988a, 1988b) shows that the fetus picks up the intonation of the mother's voice. We know the following from the earlier cited research and from work by DeCasper and Fifer (1980), Spence and DeCasper (1982, 1986), Eisenberg (1976), and Querleu (1989):

- The fetus hears by at least four and a half months in utero.
- Newborns prefer the voice of their mother over other voices.
- More specifically, they prefer her intonation pattern.
- Newborns prefer familiar stories and poems read by their mothers to non-familiar ones.

- At two months, French babies (the only ones studied) distinguish between individual syllables.
- One-day-old babies synchronize their movements to an adult's speech articulation.

Gilmor (1989) provides a summary of the genesis of listening and the Tomatis Method. Tomatis contends that during the pregnancy, especially the last half, the intonation, richness, and emotional coloring of the mother's voice are important determinants of the desire to deploy one's listening for communication with the external world. The rhythm and structure of the language spoken by the mother will also be imprinted on the nervous system of the developing fetus. Everything except the semantic meaning of the prenatal listening experience will be registered and stored for future reference. But what is most important is the kindling of the desire to communicate. An intriguing research study was done in Paris (Tomatis, 1987) in which several groups of pregnant mothers were followed at two hospitals. Groups of mothers, who did the Tomatis program for pregnant mothers, were compared to a control group of mothers, who received normal expectant mother medical care. The physicians attending the women made multiple observations and data collection during and after the delivery. The Tomatis babies had a quicker, easier delivery, had a higher birth weight and higher Apgar scores. The group differences were significant.

The inability to hear the natural mother's voice may have a traumatic emotional impact on infants, regardless of the reason (a physiological difficulty, developmental delay, absence of the mother, or extended physical separation from the mother due to adoption, accident, illness, or maternal death). A well functioning ear may develop poor functioning as a result of emotional loss of the one familiar connection between fetal and birth worlds—the mother's voice. If the infant decides to tune out some sounds in self-defense, he or she, through disuse, may not be able to tune in at will later. At other ages when the infant, child, adolescent, or adult suffers an accident, illness or emotional or physical trauma, the person can close off or tune out their environment because the experience is not safe or desired. The tuning out over a period of time requires a retraining of the ear to achieve its potential. The Tomatis Method accomplishes this quite efficiently.

The ear has strong connections with the central nervous system. Tomatis describes how the rudimentary vestibular system precedes and provides the starting point for the evolution of the central nervous system. Early on, Tomatis delineated that the cochlea and vestibule are one system with two ways to analyze movement. Phylogenetically, the vestibule analyzes gross motor movement, those within the body, through the connections with the muscles of the body. The cochlea analyzes the finer movements of air and bone, smaller acoustical type movements, perceived as sound. Thus, the vestibular (balancing) and cochlear (decoding of sound) functions of the ear are joined in a single system.

Tomatis defined the many functions of the human ear so as to understand the ear's role in learning and the development of consciousness. According to Tomatis, the human ear has at least the following functional capabilities, which can be altered at any age:

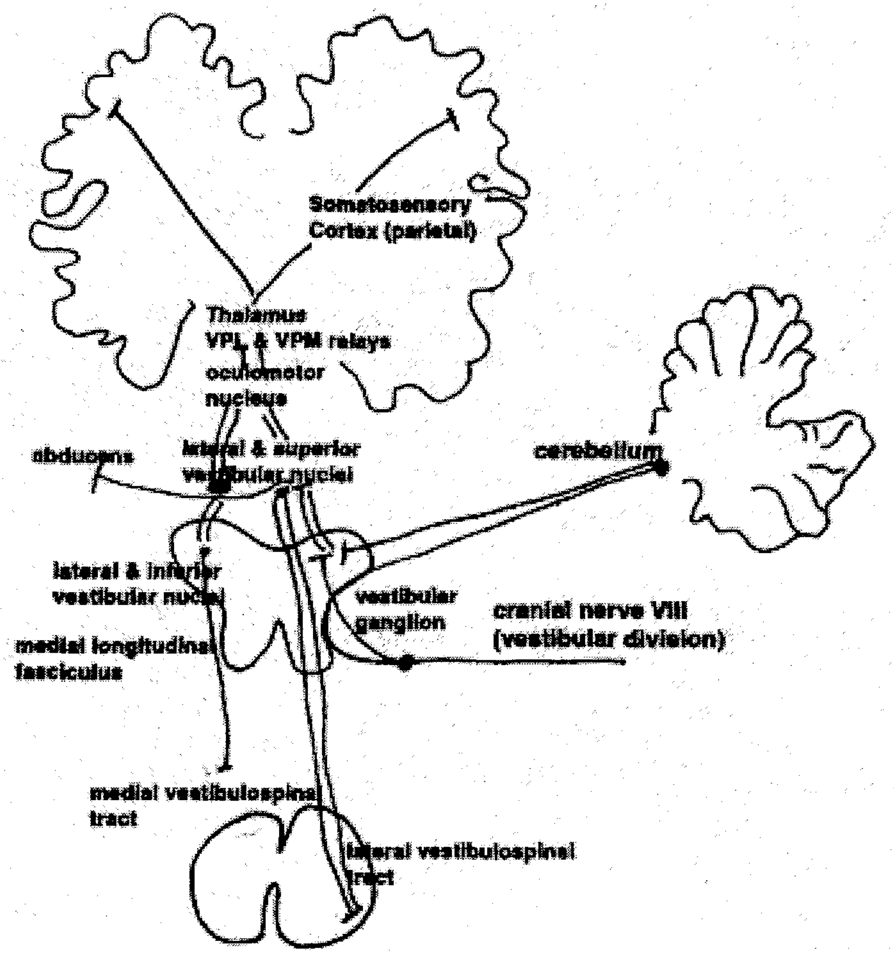
- To transmit energy, a cortical charge, to the brain
- To establish equilibrium and stimulate neuro-vegetative balance
- To perceive sound (hear)
- To locate sounds spatially
- To integrate information from sound and motor movements to enable the development of verticality, laterality, and language (Tomatis, 1971, 1978)
- To establish a right lead ear for efficient audio-vocal control

- To attend to and discriminate between sounds we want to hear and to tune out those we do not want to hear

The Tomatis theory further describes a neurological integration by developing the neurological connections of what he termed "The Three Integrators." Tomatis understands the ear to be neurologically aligned with the optic (2nd), oculomotor (3rd), trochlear (4th), abducens (6th), and spinal-accessory (11th) cranial nerves, by coming under the control of the acoustic nerve via what should correctly be called the audio-opto-oculo-cephalo-gyro cross-over. This is a major mechanism of reception and integration of perception (Tomatis, 1974a).

The Three Integrators are the foundation for three areas of development, considered to be unique to humans: verticality, laterality, and language (Tomatis 1971, 1978). All of these are required for developing good audio-vocal control.

Tomatis felt that the influence of the ear can be felt at every level of the nervous system. He saw the Vestibular Integrator (Figure 1) as the mechanism that actually pushes the organization of the nervous system. Vestibular information reaches the brainstem via the



vestibular division of cranial nerve VIII, a collection of primary afferent fibers with cell bodies in the vestibular ganglion. The peripheral processes of cranial nerve VIII innervate hair cells in the utricle, saccule, and semicircular canals; and the central processes terminate in the vestibular nuclei of the rostral medulla and caudal pons. Anatomically, the vestibular nerve presents itself at every level of the medulla and is thereby indirectly connected with all the muscles of the body. There is not a muscle that does not depend on the vestibule for its tone, equilibrium, and relative position with relation to the whole body (Tomatis, 1979).

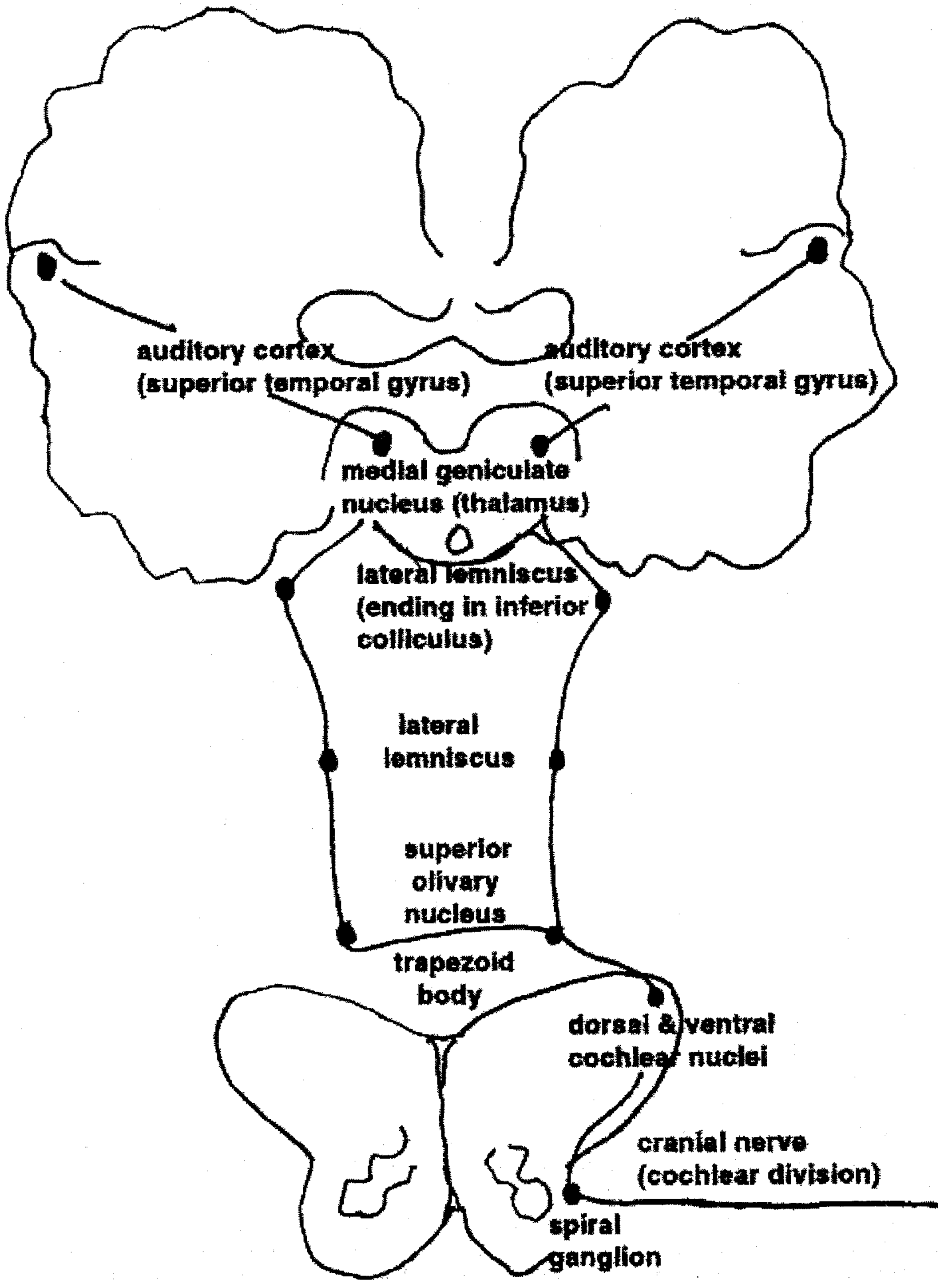
From there, the connection goes to the homolateral vestibule-spinal tract and contralateral vestibulo-spinal tract, which descend through the spinal column to connect with the receptors in the bones, joints, muscles, and skin. These connections mediate postural responses (changes to compensate for tilts and movements of the body) by innervating motor neurons for antigravity muscles at all levels of the spinal cord. If you have ever spun yourself around until you felt dizzy and staggered as you tried to walk, then you have experienced the effects of excess activity in your lateral vestibulospinal tract. Sensory information returns from the receptors to the cerebellum through the tracts of Fleschig and Gowers (not shown). The other pathways project from the vestibular nuclei to the abducens, trochlear (not shown), and oculomotor nuclei. The latter mediates eye movements that compensate for head movements—the vestibuloocular reflex. For example, if you fix your gaze on an object and hold that fix even though your head is moving (as in a moving car), you have activated the vestibuloocular reflex.

Abundant interconnections between the vestibular nuclei and the cerebellum assist in these tasks. Connections are made in the cerebellum with the emboliform nucleus, which projects to the central portion of the red nucleus and returns information by way of the rubrospinal tract (not shown). Other connections in the cerebellum are made with the globose nuclei, which return through the inferior olivary nucleus and the olivospinal tract down to the spinal column (not shown). There are also interconnections between the reticular formation (important in attentional processes and sustaining arousal) and the vestibular nuclei.

Finally, there is a projection from the vestibular nuclei to the thalamus, and from there to the cerebral cortex. The thalamic relay is in a small nucleus in the inferior part of the thalamus, near the ventral posterolateral (VPL) and the ventral posteromedial (VPM) thalarnic nuclei. Among other things, these connections assist changes in head position or motion to reach consciousness. Secondary vestibular fibers reach the thalamus bilaterally by traveling with the auditory fibers of the lateral lemniscus or via traversing the reticular formation. Both of these thalarnic nuclei project to the somatosensory cortex (parietal areas) via the posterior limb of the internal capsule. Thus, among other things, the Vestibular Integrator provides information for body image, kinesthesia, and the sensation of bodily movement and position in space.

Closely associated with this integrator is the second system, which Tomatis calls the Visual Integrator (not shown). The connections between the ear and the eye (Visual or Spatial Integrator) start with vestibular information to the vestibular nuclei, through the vestibulo-mesencephalic tract to the nuclei of the cranial nerves III, IV, and VVI (sources of motor nerve function for the eye).

Third is the Cochlear (linguistic) Integrator (Figure 2), which gathers nerve tracts from the dorsal and ventral nuclei, connects with the vestibular analyzers through the surface network on the cerebellum, then returns to stimulate the brain through the frontal and parietal nerve tracts and some of the fronto-pontic and parieto-pontic fibers (not shown).


auditory cortex
(superior temporal gyrus)
auditory cortex
(superior temporal gyrus)
medial geniculate
nucleus (thalamus)
lateral lemniscus
(ending in inferior
colliculus)
lateral
lemniscus
superior
olivary
nucleus
trapezoid
body
dorsal & ventral
cochlear nuclei
cranial nerve
(cochlear division)
spiral
ganglion

Tomatis believed the Cochlear Integrator to be the major inductor that gradually guides the nervous system to its human fulfillment.

The Cochlear Integrator provides the means by which sound stimulating the cochlea travels to the brain stem through the vestibular-cochlear cranial nerve and up the lateral tract of Reil to the medial geniculate body of the thalamus. Tracts project from the thalamus to the auditory reception areas of the temporal lobe. Multiple tracts project from the thalamic relay nuclei to the cerebral cortex. Tomatis said that the thalamus is of central importance in understanding why his Method works. In fact, the rich interconnections between the brain and the ear are what allow the stimulation of the Tomatis Method to prompt language development in developmentally delayed children, to improve auditory processing, to increase visual-spatial processing and visual memory, and even to increase Performance IQ with prolonged stimulation (Gilmor, 2000). Neuropsychologically, effects of this nature are understood to be the result of dynamic changes in how the brain functions so as to mediate specific human abilities, behaviors, and aptitudes.

Neuropsychology of the Tomatis Method

Neuropsychology is the study of the relationships between the brain and human behavior, growth and development, and disease and deficits. In order to understand the effects of the Tomatis Method on the brain and the nervous system, we turn to the burgeoning science of neuropsychology.

There are several basic scientific principles that are assumed in almost any discussion of changes in the nervous system or the brain, such as from cognitive rehabilitation or from the Tomatis Method. First, our nervous system is designed to respond to stimulation from our senses (sight, sound, smell, taste, touch). A second basis principle is that stimulation can encourage growth.

One way in which this is understood in the brain is that stimulation can increase cerebral blood flow, which results in more nutrients and oxygen reaching a certain area. This is believed to promote growth, at least in the form of dendritic branching. The early stimulation studies in cognitive neuroscience (Hebb, 1966; Hunt, 1961) were based on the assumptions that enrichment leads to a proliferation of neural structures and/or neurochemistry changes, while deprivation (sensory or environmental) could lead to a loss of intellect and related cognitive abilities.

The Tomatis Method is based upon these principles and on the belief that sound, particularly high frequency sound, is an important form of stimulation for the brain. Scientists have shown that 80 percent of the 24,000 hair cells in the cochlea respond to sounds 3000 Hz and above. Tomatis believes that such stimulation activates neural pathways and, in the developing fetus and infant, acts as an organizing principle for the developing nervous system.

Another underlying principle is that neural plasticity is believed to be greatest during the first eight years of life for species specific developmental abilities (Bruer, 1999). Therefore, the optimal time to intervene to assist or encourage faulty development of the nervous system would be the early years. It is believed that there is considerable redundance in the neurological system. If one part is damaged or incomplete in its development, other parts can be encouraged to provide the necessary information to allow the individual to at least regain some of their function. Recent findings have modified and clarified our understanding of the brain. It is now known that even in adults, the brain continues to change and develop throughout life via sensory stimulation from one's experiences (Bruer, 1999).

The receptor sites for the neurotransmitters are definitely plastic. This is, of course, the neurological basis underlying such problems as depression.

The final neurodevelopmental principle underlying the Tomatis Method is that development, by definition, means that something does not happen immediately or right away. Growing taller is developmental. Language development occurs over a period of time. Nerves grow slowly. The Tomatis Method provides stimulation, which is believed to promote nerve growth. The method is designed such that stimulation is provided in bursts of intensity, with periods of rest interspersed, over a period of months. Thus, there is time built into the Tomatis Method for the growth that has been prompted. Some people continue to listen over several years to boost their previously achieved gains. Results are increased ability to listen to and know self, to listen to and speak with others, and to expand one's desire to learn and explore the cosmos. Applications, therefore, range from developmental to self-actualization.

As has been described, the Tomatis Method works on a wide variety of problems because of the rich interconnections between the ear and the brain stem, the cerebellum, and the higher cortical centers. Thus, problems and deficits that have a neurological basis can be helped by a specific application of sound stimulation with certain characteristics. Some of the problems to which the Tomatis Method has been applied include head injury and other neurological injuries (such as stroke), developmental delays, autism/PDD, Multi-System Sensory Disorder and other types of brain damage from birth, attention deficits, and learning disabilities. All of these problems have in common the fact that the brain has been damaged or is immature or is not working properly because it failed to develop normally.

For example, in the case of head injuries, the Tomatis Method is particularly helpful when the injury has been to the brain stem as the redundance of the vestibular network allows other areas to be encouraged to take over function of damaged areas by the stimulation. Attention and memory are improved by way of stimulating the attention pathways of the reticular activating system, through the thalamus and on to projections in the frontal lobes. Sensory integration is definitely improved by virtue of the pathways through the thalamus, the cerebellum, and the parietal projections. Reaction time and auditory information processing speed are likewise increased.

The pathways in the brain through which the sound stimulation travels determines some of the benefits that the person may derive. In other words, different abilities (such as language, attention, visual memory, etc.) are associated with different areas and pathways of the brain. It is now known that there is no one "music center" in the brain. The brain processes music in both the left and the right hemispheres. Listening to and attending to music certainly involves the auditory system and its highest level, the auditory cortex (temporal lobes). But both the left and right temporal lobe structures are involved.

Research and experience with the Tomatis Method shows that it provides a great benefit for developing language and auditory processing abilities. Through neuropsychology we are beginning to pinpoint specific problems to specific areas of the brain. The popular press (Blakeslee, 1994) reported Tallal's hypothesis that "dyslexia" may be due to a fundamental flaw in the left temporal lobe, which misperceives the rapid sounds of speech. This type of information provides an illustration of how the Tomatis Method can be advantageous in remediating speech and language deficits, since the sound/music stimulation affects both the left and the right temporal areas of the brain.

Bruer comments on the research by Merzenich et al. (1996) in his new book, *The Myth of the First Three Years* (1999). He notes their training method of using temporallymodified speech sounds, with language impaired children, is counterintuitive, and that the stimuli that helped children's brains reorganize were not normal speech sounds, clearly presented, but rather highly distorted speech sounds that would never occur in a child's normal linguistic environment (Bruer, p. 140). Those who have listened to the sounds of Mozart presented through the Tomatis EE are no strangers to distorted sound. Decades before Merzenick and Tallal, Tomatis developed ways to distort sound (high frequency filtered Mozart, with electronic gating) in such a manner as to tune in listeners to what they were missing. Thus, the method opened new pathways in the brain, which provided a wider perception of incoming information, and even created more of a desire to communicate with and learn from others.

Research

A number of rigorous research studies were undertaken in the 1970s and 1980s in Canada in an attempt to quantify the effectiveness of the Tomatis Method. Two of these were conducted by neuropsychologists of international reputation, Barbara Wilson and Byron Rourke. The original research was never published; however, a meta-analytic study, including the data from Drs. Wilson and Rourke, has been completed and is in publication (Gilmor, 1999). Results of the meta-analysis are remarkably strong and indicate that the Tomatis Method can significantly increase Performance IQ, auditory processing, and visual memory. The increase in Performance IQ is actually highly consistent with the transient "Mozart effect" (Rauscher et al 1997). Spatial reasoning is a primary factor in the Performance Scale of the Wechsler Intelligence Scales and the Stanford-Binet. However, the significant increase in Performance IQ found in the children who received the Tomatis Method is not transient. The increase is lasting.

Gilmor's meta-analytic study includes four previously unpublished research studies and one published study evaluating the efficacy of the Tomatis Method in children with learning and communication disorders. Positive effect sizes were found for each of the five behavioral domains analyzed: linguistic, psychomotor, personal and social adjustment, cognitive, and auditory. The results suggest additional research is warranted, and they are consistent with clinicians' reports of beneficial effects.

Several research studies were conducted and published in South Africa with a population of learning disabled children (van Jaarsveld and du Plessis, 1988). One, in particular, measured changes in self-esteem and the ability to describe emotions in words better. The brain areas that correlate with emotional responses to music include the paralimbic regions (Blood et al., 1999). Another study showed increased changes in language ability following Tomatis training for a group of learning disabled children versus a group that received counseling and another control group with no treatment (du Plessis and van Jaarsveld 1988). Thompson (1993a) provides a good overview of research and shows how we have long known that auditory processing problems are at the source of many learning disabilities.

Offshoot Technologies from Tomatis

Since Tomatis introduced this Field of Sound Training, no fewer than a dozen offshoot and related systems have been introduced. The offshoots take one or more aspects of the Tomatis Method, including formerly patented features that are now in the public domain, and produce media distributed by CD or audio cassette. Many people making new devices

TABLE 1
Sound Training Methods Requiring Professional Training at the Start of the 21st Century

Method (if active work is included or optional, it is noted)	Acknowledge Tomatis (X) Available in US (Y) In develop-ment (D) Professional training in US available (P)	Content of Sound 1 Mozart 2 Gregorian Chant 3 Classical 4 Nature 5 Folk/ Children's 6 Language 7 Mother's Voice Filtered 8 Rock 9 Tones	Applications 1 Educational 2 Clinical 3 Relaxation 4 Musical 5 Developmental 6 Rehabilitation 7 Language 8 Rhythm, Motor 9 Cognitive 10 Auditory 11 Behavioral	Proof of claim 1 Anecdotal 2 control gr 3 pre – post 4 double bl 5 Non parametric	FDA Status based on claims 1 Not required 2 Req, not doing 3 Req, doing
EQUIPMENT					
Patents, Air-Bone Delay, (Active Voice noted)					
Tomatis (active)	X Y	1 2 3 4 5 6 7	1 – 11	1 2 3 5	2
Thompson (active)	X D	1 2 3 4 5 6 7	1 3 4 5 7 9 10 11		1
Thompson	X D	1 2 3 4 5 6 7	1 3 4 5 7 9 10 11		1
Without Patents (active or non-delay air+bone options noted)					
Berard (no longer imported)	X Y	3 5 8	1 2	1 2 3	2
BGC (no longer mfg)	X Y	3 5 8	1 2	1	2
Joudry (active optional)	X Y P	1 3 5	1 2	1	1
Madaule (active optional)	X Y P	1 2 3 5	1 2	1	1
Samonas/Sonas (non-delay bone+air optional)	X Y P	1 3 4	1 2	1	2
Earliest Hearing Adventures	Y P	3 5 8	1 2	1	1
Bioacoustics	Y P	9	2	1	2
CDS, CASETTES					
With Patent for wave form					
Lowrey	X Y	1 3	2 3	1	1
Without Patents					
Joudry	X Y P	1 3 5	1 2 3	1	1
Samonas/Sonas	X Y P	1 3 4	1 2	1	1
The Listening Program	X Y P	1 3 4 5		1	1
Hemi-sync	Y P	1 3	1 5	1	1
Bioacoustics	Y P	9	2	1	2
CD ROM *W/proprietary protocol*					
Fast Forword	Y P	6	1 2 7	1 2 3 4	1

and new types of sound delivered via CDs and other media typically acknowledge the research findings and techniques of Tomatis as a major source for their work. A few of the offshoots have patents or new methodologies. Table 1 shows a summary of these offshoots and information about their recognition of Tomatis, availability in the United States, sound content, applications, method of proving claims, and FDA status, if required. Most of the new systems of training make claims of "effectiveness as good as Tomatis," yet no research exists to substantiate their claims. Thompson and Andrews (1999) describe a number of technologies and methods that have evolved from the inception of the Tomatis Method.

Conclusion

Understanding the theories and neuropsychological basis for the Tomatis Method can open the door for additional research and promote the development of new and effective sound training and stimulation methods. As humans learn more about the ear, they can learn more about themselves and what may be possible to achieve in the future.

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