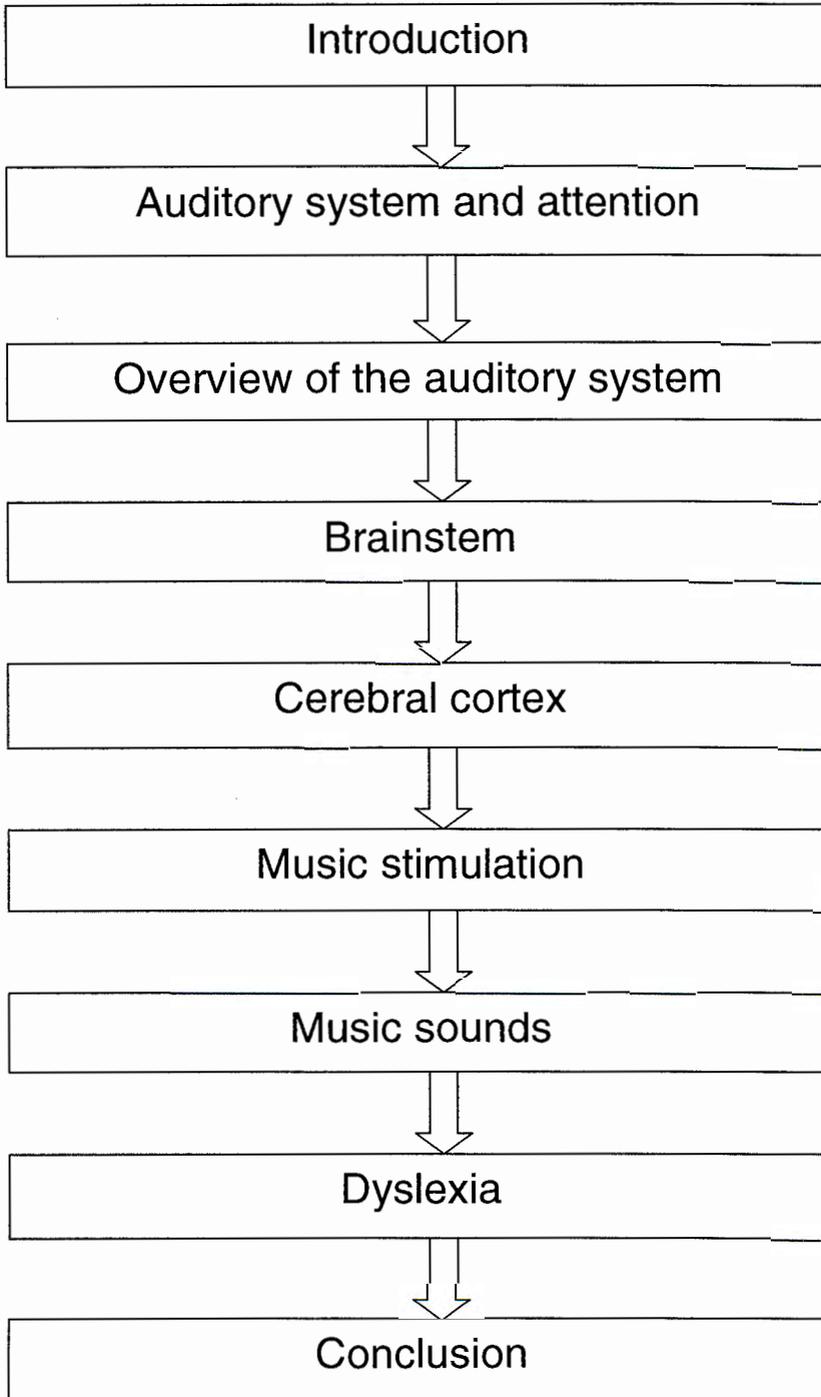


Overview of chapter 3



3.1. Introduction

The educational and medical fields have different approaches on how to handle and help learners with attention problems. The only point where there might be some interest in jointly addressing the problem of attention, is when the teacher decides that the learner has a problem in paying attention (and the teacher is most often correct in this observation) and then demands that the learner must be put on a stimulant medication. If the parent does not want to comply with this demand the learner is threatened with expulsion from the school (Thornton, 2006:20).

Yet, there are several theories explaining the mechanisms by which a learner pays attention, or indicating which conditions are necessary to be able to pay sustainable attention (Fehmi & Robbins, 2007:146; Thornton, 2006:48; Papolos & Papolos, 2000:37; Incorvia, Mark-Goldstein, Tessmer, 1999; Wise, 1997:190) However, these theories remain suppositions. That leaves the door open for other explanations of why one person can pay effective attention with less effort than the next person. Different avenues that might have an influence will be explored, even if the relevance is initially not so clear.

It has been postulated that the most effective intervention for learners on the continuum of disorders classified as a lack of attention control, is a three-legged approach (Personal communication with Prof Hanlie Moolman-Smook (bio-medical scientist) 2009):

- The one approach will be **bio/medical** intervention where pharmaceuticals such as stimulant medication, anti-depressants and sleeping pills are prescribed, and/or supplementation or dietary intervention is evaluated. With regard to the latter, for instance, Richardson et al. (2000:69) found that reading problems may be associated with relative deficiencies in certain highly unsaturated fatty acids. In learners with attention deficits these physical signs have been shown to correlate with poorer spelling and auditory working memory. Supplementation with Omega 3 fatty acids appears to increase the ability to pay attention in at least some learners with attention difficulties (Belanger, Vanasse, Spahis,

Sylvestre, Lippe, L'heureux, Ghadirian, Vanasse & Levy, 2009:89; Vaisman, Kaysar, Zaruk-Adasha, Pelled, Brichon, Zwingelstein & Bodennec, 2008: 1170).

- The second intervention addresses **behavioural or educational** aspects where the learners are assisted by:
 - teaching them to pay attention to selective stimuli;
 - preferred classroom seating is arranged;
 - effective study skills are taught; and
 - coaching is offered.
- Thirdly, interventions are chosen that could change the way a learner is paying attention by altering the brain developmental aspects of the attention cause of the attention problems. Occupational therapy and other movement-based interventions such as Braingym, Integrated Learning Therapy, as well as sound therapies such as Berard AIT, and Neurofeedback fall into this category (personal communication – Prof Hanlie Moolman-Smook – biomedical scientist, 2009).

The aim of this chapter is to highlight the relation between learners with attention problems and the possible defective listening skills of these learners. If there is a relation between listening skills and attention, this knowledge may be useful to devise an effective intervention programme to use auditory stimulation to ameliorate attention problems. The study of the effect that auditory stimulation has on the brain is still in its infancy and the researcher hopes that this study might influence other researchers to undertake studies on a bio-medical field that might be of benefit to learners.

As part of understanding this relationship between listening and attention, this chapter will discuss the functioning of the auditory system. If the re-training of the auditory system has an effect on the efficiency with which a learner can pay attention, it is necessary to understand the route that sound waves travels from the outer ear to the auditory centre in the temporal lobes of the cortex. In this way the precise point where the stimulation and changes that may follow from sound therapy take place might be pinpointed. Better understanding of the circuits that respond to auditory stimulation will advance our understanding of the neurobiological mechanisms underlying individual differences in attention control and may lead to more effective educational and intervention strategies (Tallal & Gaab, 2006:1).

The process through which the learner becomes aware of auditory input will also be discussed in this chapter. Attention problems will be highlighted, especially the link between sound perception, and the skill of paying voluntary controlled attention. The effect of the re-training of the auditory system might result in changes on a biochemical basis (Jaap Panksepp in SAIT, 1995:2). To try and determine where and how these changes take place, a deeper knowledge of the auditory system as well as brain areas that might be influenced, are necessary (cf. 3.7). In SAIT (1995:3) different theories, which explain how the re-training of the auditory system works physiologically, are documented. These theories, which will also be discussed in this chapter, pinpoint different areas in the auditory pathway where the changes might take place; to understand these theories better, the auditory system will also briefly be explained (SAIT, 1995:3) (cf. 3.4).

Furthermore, the role of music in the amelioration of functional problems will be highlighted. Music has been used through the ages to alter mind states. According to O'Donnell (1999:1) Thomas Jefferson wrote the Declaration of Independence while playing his violin. The violin was also the instrument that ignited Albert Einstein's genius. O'Donnell (1999:5) reports that Napoleon understood the enormous power of music by saying: *"Give me control over he who shapes the music of a nation, and I care not who makes the laws"*.

3.2. The auditory system and attention

Our perception of the world and reality comes from our senses. When the ability of one of the senses is enhanced, for instance the auditory system, it actually changes the way the world and reality are perceived (Goldman, 2008:26). The information processing capabilities of learners diagnosed with the inattentive subtype of ADHD has been characterized as having a sluggish cognitive tempo (Weiler, Bernstein, Bellinger & Waber, 2002:1). If the centre in the brain that is the source of this deficit can be traced, the learners can possibly be helped more effectively.

Riccio, Cohen, Garrison & Smith (2005:1) and Witton (2010:83) have found that measures of auditory processing are actually also sensitive measures of attention,

thus it is not surprising that there is a high comorbidity of auditory processing problems and attention problems.

Auditory processing disorders include elements of both attention and memory problems during auditory processing and may manifest itself in a myriad of behaviour problems across settings. Symptoms that might be seen in learners are withdrawal, conduct problems, and depression, as well as anxiety, learning problems, and deficits in social skills and leadership skills. Parents find that these learners experience somatisation (their learning deficits surface as headaches, stomach aches, etc.), while teachers experience the auditory processing problems as a lack of sustained attention (Riccio, et al, 2005:1).

Tallal and Gaab (2006:382) assert that learners with language-based learning problems such as reading disabilities, dyslexia, auditory processing disorder and working memory deficits, often display problems with attention. This can be a result of the stress and feelings of inadequacy experienced by learners because of their learning problem. Better understanding of the origins of the auditory perception problems will advance our understanding of the underlying neurophysiological mechanisms that are involved and will lead to more effective educational and intervention strategies (Tallal & Gaab, 2006:382).

Research (Anderson, Skoe, Chandrasekaran and Kraus, 2010: 4922; Parberry-Clark, Skoe and Kraus, 2009:14100; Graham, Robinson and Mulhall, 2009:1; Desaulniers, 2009:1) suggests that music training can have a positive effect on cognition and attention and it is therefore important to understand how the brain is activated and neuron growth is stimulated by music.

3.3. Overview of the Auditory System

(cf. Annexure L - Figure 3.1)

Anatomically the ear has three distinguishable parts: the outer ear, middle, and inner ear. There are many obstacles that can affect the flow of sound from its inception at the outer ear to its decoding in the brain. Any of these obstacles will affect the reception of sound and will thus lessen the impact of this sensory input on the brain

and on perception (Berard, 1993:8). Since this deliberation is at the centre of the discussions in this chapter it is important for the reader to keep the aforementioned fact in mind.

3.3.1. The Outer Ear

The pinna or auricle funnels sound into the ear canal and amplifies the sound with 5 decibels (dB). Total or partial obstruction of the ear canal by wax or the presence of a foreign body, are enough to reduce the sound stimulus that will reach the brain by many decibels (Berard, 1993:8).

3.3.2. The Middle Ear

Although the structure and movement within the middle ear is relatively simple, Drs. Tomatis and Berard have stressed its importance in understanding how auditory stimulation might bring about changes in the individual's functioning. Sounds can be blocked involuntarily through the restriction of movement in the middle ear through a number of mechanisms, some of which are described below. This will influence perception of sounds received and an additional lack of attention to received information (SAIT, 1995:2).

The tympanic membrane vibrates according to the sound energy coming through the ear canal. This membrane can be thickened or affected by eczema, or even torn. Its mobility can also be hampered by the presence of excess liquid or pus in the inner ear or by defective functioning of the Eustachian tube, so that air pressure is not equal on both sides (Berard, 1993:8).

However, when the tympanic membrane is capable of vibration, sound wave information next travels across the air-filled middle ear cavity via the three smallest bones in the body, known as the malleus, incus and stapes, collectively known as 'ossicles'. The tensor tympani and the stapedius muscles are responsible for providing the proper tension to the ossicles. These muscles coordinate a reflexive pulling and relaxing, which regulate movement of the three ossicle bones, in order to protect the inner ear. This involuntary movement is called the acoustic reflex (Stach, 1998: 53).

During the acoustic reflex, the muscles contract, allowing only restricted movement of the ossicles, which will reduce transmission of incoming sounds via the ossicles, with a resultant loss of auditory sensory stimulation (Berard, 1993:9).

Autistic children and those on the autistic spectrum, often have problems with the acoustic reflex and the muscles in their ears might be permanently contracted. This will influence the sounds that they perceive and could have an influence on the way that they pronounce words. Learners with attention problems often fall on the autistic spectrum, and thus will also be influenced by the malfunction of these muscles (SAIT, 1995:2).

The movement of the ossicles can also be severely restricted by fluid produced during otitis media (middle ear infection) or by the presence of hardened tissue in the middle ear. Although all the learners with attention problems may not have middle ear infection all the time, a high percentage of these learners do have allergy and food sensitivity problems which can cause middle ear infections. An infected middle ear will obstruct the sounds that are transmitted to the inner ear, especially those in the lower frequencies (Berard, 1993:9).

According to Schmidt (2004:34), Offit (1999:29) and Block (1998:44) learners with food sensitivities will most probably have had these sensitivities since they were small children. Infected middle ears and ear pain are usually treated with antibiotics. The number of antibiotic treatments taken in the early developing years is often related to attention problems in later years. Broad spectrum antibiotics can even cause hearing loss (Schmidt, 2004:34; Offit, 1999:29; Block, 1998:44).

Any alteration in the middle ear cavity will reduce transmission of incoming sounds (Berard, 1993:9). When a Listening Profile (cf. 4.5.5) is done before Berard AIT (cf. 4.5), it is often easy to read off the graph if there are some blockages in the middle ear. The lower sounds have difficulty travelling through the congested middle ear and the sound of the audiometer has to be turned louder before the person responds to the presented sound (Brockett, 2003).

The following two theories, focusing on the role of the middle ear, explain how individuals may benefit after receiving Berard AIT (cf. 4.5).

- One theory propounds that the muscle tension between the tensor tympani and stapedius muscles is not adequate for proper functioning of the ossicles (SAIT, 1995:3:2). As Berard AIT listening sessions (cf. 4.5) exercise and strengthen the muscles in the middle ear, it encourages development of the correct muscle tension and efficient transmission of sound so that the exact sounds that have been received in the outer ear, is emitted to the inner ear (Berard, 1993:7).
- SAIT (1995:3) proclaims that a second explanation is that the tensor tympani muscle and the stapedius muscle no longer work in a coordinated way to form the acoustic reflex. This may result from a trauma to the middle ear, such as a middle ear infection. By listening to very energizing, modulated music, the two muscles are stimulated and prompted to work in unison to again produce the acoustic reflex (SAIT, 1995:3).

Berard (1993:71) asserts that hypersensitivity to noise can be a stressful, as well as a painful experience. If the acoustic reflex is elicited and the learner reflexively blocks out irritating sounds, the learner will be unable to process incoming information and signs of inattention will be displayed. Berard found that if loud sounds bothered an individual, exposure to stimulating sounds, such as Berard AIT (cf. 4.5), may allow a person to adapt auditory to intense sounds. As a result, they may consciously or unconsciously learn to ignore stimulating sounds after Berard AIT (cf. 4.5). Adaptation is a built-in mechanism which, after continuous exposure to a stimulus, reduces the perception of that stimulus. This will aid the learner in paying sustained attention to incoming information (Berard, 1993:71).

Carl Delacato (in Campbell, 2008:2) theorized that children on the autistic spectrum may have senses which are hypersensitive, hyposensitive, or experience high degrees of auditory noise. This can also be true for learners with attention problems. If the hypersensitivity to noise is present at birth or starts in the early childhood years, it may be very difficult for the child to understand what people are saying and to pay attention to the environment (Delacato in Campbell, 2008:2).

3.3.3. The Inner Ear

(cf. Annexure L - Figure 3.2)

Differentiation of the inner ear begins during the third week of gestation, and between the tenth and twelfth weeks the organ of Corti starts to form. The vestibular portions of the inner ear develop earlier than the auditory portions. By twenty-five weeks the inner ear has fully formed (Martin & Clark, 2003: 12). This means that the infant can already hear when in utero. Hearing is the first sense to be activated in utero, and it is the last sensory input that a hearing person receives when dying (Goldman, 2008:25).

Accordingly, environmental sounds can have an influence on the developing fetus and if the sounds are distressing, accompanied with heightened cortisol transmitted through the blood of the mother, the baby can be born in a heightened alert state with a lessened ability to pay sustainable attention (Hannaford, 1995:32).

When sound waves enter the ear all the systems in the auditory system are stimulated or put under stress. This effect is carried through the brainstem to the cortex where behaviour and emotional responses are affected by the auditory stimulus received. According to Goldman (2008:9) the human body is a complex vibratory system that resonates, responding to all sorts of different frequencies.

Even after birth, sound perception may be a source of stress. The more intrusions there are which deter the clear perception of sound by the brain, the greater the effect on the stress level of the individual. A high stress level causes the individual to experience an anxiety state where glucocorticoids are secreted, which result in an alert, hyper-vigilant state and which diminishes the ability to pay sustained attention (Ruden, 2003:40). Of note is that Sauvage and Steckler (2001:643) found that the corticotropin-releasing hormone (CHR), which is of relevance in mediating the stress response and anxious behaviour, are present in the brainstem as well as in the forebrain; the role of the brainstem in processing sound is discussed in paragraph 3.3.8.

3.3.3.1. Cochlea

(cf. Annexure L - Figure 3.3)

According to Martin and Clark (2003:13) the nerve that innervates the cochlea is the vestibule-cochlear nerve. The moment the auditory neurons are stimulated by the hair cells that rest on them, a change in the electrical potential occurs on the surface of each neuron. The precise means by which we hear remains unknown, but it is generally agreed that the intensity of the auditory input signal to the cochlea result in increased electrical output from the hair cells (Martin & Clark, 2003:13). If the cochlea has been affected by hereditary factors, by a circulatory problem or by side effects of medication, the prognosis is less clear, and the chance of clear sound reaching the ear is reduced (Berard, 1993:9).

Goldman (2003:13) asserts that sound can however reduce imbalances and heal the system by rejuvenating and restoring the body's own resonant frequencies. When the correct resonant frequencies are employed, they have the ability to charge the energy of failing cells, bringing them back to a state of health. Sound has indeed the power to change molecules (Goldman, 2008:13).

3.3.4. Auditory Nerve

(cf. Annexure L – Figure 3.4)

The auditory fibres extend 17 to 19 mm beyond the internal auditory canal, where it attaches to the brainstem with the cerebellum, medulla oblongata and pons to form the cerebello-pontine angle. This is the beginning of bilateral representation from a signal presented to just one ear (Martin & Clark, 2003:13). The auditory signals are transmitted to the central nervous system via this connection (Shepherd, 1994:340).

In the absence of stimulation, the auditory fibres show considerable spontaneous activity. This means that hair cells, synapses, and auditory fibres are primed to respond to small changes in stimulation, just as in most sensory systems (Shepherd, 1994:340). This may be why auditory stimulation like Berard AIT (cf. 4.5) can have such a profound effect on an individual's total sensory perception and consequently also on the sustaining of attention.

3.3.5. Vestibular system and its function

(cf. Annexure L – Figure 3.5)

The vestibular system is the sensory system that helps the body to maintain its balance, and is also located in the inner ear. It consists of two structures, the vestibule and the semicircular canals (Martin & Clark, 2003:275).

The information from the vestibular apparatus is used in three ways:

- i. To provide a sensation of movement in 3-dimensional space.
- ii. To maintain upright body posture (balance), and
- iii. To control the muscles which move the eyes (Hawkins, 2008:10).

One of the functions of the vestibular system is to coordinate the movement of the eyes with the position of the head. This organ is functionally closely connected to the cerebellum and to the reflex centres of the spinal cord and brainstem that govern the movements of the eyes, neck, and limbs (Hawkins, 2008 :10). The eye movements which are generated by activation of the vestibular system are called vestibulo-ocular reflexes or eye movement "reflex" and is very important: it allows us to keep our retina fixed on the same point in visual space both during head movements (Martin, 1998:119).

Brockett (2003) asserts that if attention is enhanced through the perception of sound, it might be because of the sound stimulation, but it could also be because of the heightened influence on the accompanying senses. Specifically, the visual and auditory nerves run alongside one another, before it enters the brainstem. There are anecdotal examples of people gaining visual acuity after an auditory intervention (Brockett, 2003).

3.3.6. Vestibular – Cerebellum connections

(cf. Annexure L – Figure 3.6)

SAIT (1995:2) states that the cerebellar-vestibular system is the sensory-motor processing centre of the brain. The vestibular system is connected to the cerebellum via the vestibular nerve. Disturbances in the vestibular – cerebellum communication is considered to be one of the deficits underlying dyslexia, and other learning disabilities;

vestibular stimulation and rotation is thought to open the door for further remediation (Pope & Whiteley, 2003:109; Levinson, 1990:67; 1988:983). Berard AIT (cf. 4.5) may be one method of stimulating the cerebellum via the vestibular system to help reorganize a dysfunctional system (SAIT, 1995:2).

According to Sally Brockett (2003:23) the Cerebellum-Vestibular system theory is a reason why so many changes occur after Berard AIT training, that on the surface do not appear to be related to the auditory system, or specifically, to the normalization (flattening) of the listening profile (cf. 4.5.5). This theory explains why individuals report that they can taste and smell things better and are no longer tactilely defensive after Berard AIT (cf. 4.5) training. It also supports parents' and teachers' claims that the child has better balance, motor function, and handwriting. The accounts of improved eye contact, eye-hand coordination and eye alignment are also explained by this theory. The observation that some people could suddenly tell time, whereas others could understand left/right directionality, is also justified by the cerebellum-vestibular theory (Brockett, 2003:23).

According to Brockett (2003:23) the vestibular system is responsible for the following processes which can also influence the sustaining of attention:

- The command centre for sensory processing;
- an influence on the eye and neck muscles, and the muscles of the body;
- postural and equilibrium responses;
- vestibular-reticular interactions to keep arousal level balanced;
- emotional development and behaviour;
- digestive system; and
- learning.

Frick and Shirley-Lawton (1994:1) found that the people with known vestibular processing dysfunctions make the greatest gains from Berard AIT (cf. 4.5). The improvements may occur in the areas of movement perception and security, overall arousal, organization and social-emotional response. This may occur since the vestibular system acts as a central reference point from which all other sensory information is composed (Frick & Shirley-Lawton, 1994:1) .

3.3.7. Cerebellar Functions

According to Brockett (2003) the cerebellum modulates or is involved with:

- emotion, anxiety, affective behaviour and higher cortical functions;
- mental imagery;
- anticipatory planning;
- some language processing mechanisms;
- shifting of attention;
- regulation of speed, consistency and appropriateness of cognitive processing;
- sensory data acquisition and discrimination;
- cognitive processes that modulate motor behaviour and planning;
- visual spatial organization, spatial orientation, visual motor function;
- working memory and long-term memory; and
- complex problem-solving.

If the cerebellum is functioning optimally, the above processes will be in place to form a strong network which will enhance the learner's executive and attention skills (Brockett, 2003:24).

3.4. Brainstem

(cf. Annexure L – Figure 3.7)

The brainstem, consisting of the medulla oblongata, pons Varolii, and midbrain, connects the spinal cord to the forebrain and the cerebellum. Although Focoetti, Lorusso, Cattaneo, Galli and Molteni (2005:70) interpreted attention focusing as a parietal dysfunction, later research showed, however, that it is possible to detect neural encoding deficits through speech-evoked brainstem responses as early as the in the auditory brainstem (Johnson, Nicol, Zecker, Kraus, 2007:376).

The following functions are located in the brainstem:

3.4.1. Speech Perception

(cf. Annexure L – Figure 3.8)

When auditory information is received, sound recognition is processed parallel to sound localization, but in anatomically different networks. Parallel processing increases the speed of processing and enhance multisensory interactions. This will increase adaptability in perceptual learning (Mathieu, 2008:143). These processes, as well as the discrimination of rapid acoustic change, are impaired in learners with learning and attention problems. The discrimination deficits occur in the auditory pathway before conscious perception. This should influence the choice of therapeutic interventions (Kraus, McGee, Carrell, Zecker, Nicol, Koch, 1996:971).

According to Marler and Champlin (2005:189) the presence of successive sounds can delay the neural response. The cause of the delay at the level of the brainstem is not known, but it may be due to disruption of synchrony, activation of alternate pathways, increased inhibition or a combination of these and other factors (Marler & Champlin, 2005:189).

Speech perception difficulties often occur in learners with poor temporal resolution. This means that the processing of an auditory stimulus can take several seconds. As the learner is still processing the information, new auditory information is being added, which floods the processing system and attention problems are experienced by the learner. These learners have difficulty in separating sounds occurring in rapid succession and can cause impairments in language acquisition (Johnson et al, 2007:1829). Speech processing is disrupted already at brainstem level in children with autism (Russo, Nicol, Trommer, Zecker and Kraus, 2009:557) and other learning difficulties; some research suggests that training improves the brainstem-related delay (King, Warrier, Hayes and Kraus, 2002:111).

3.4.2. Working Memory

(cf. Annexure L – Figure 3.9)

According to Papageorgiou, Anagnostopoulos, Giannakakis, Sakelariou, Tsiaparas, Paraskevopoulou, Nikita, Rabavilas and Soldatos (2005:1829) pre-attentive processing problems occurring in the brainstem, is the source of problematic auditory cognition and working memory deficits. These problems are strongly related to symptoms of inattention.

Neurophysiological impairments are strongly associated with the inattention symptom dimension (Martinussen & Tanneck, 2006:1073). This inattention symptom is also found in memory problems of older learners and may be caused by a deficient executive process: the cognitive processes will not function optimally (Pollak, Kahana-Vax & Hoofien, 2008:62).

Research done by Montgomery, Morris, Sevcik and Clarkson (2005:450) showed that learners with reading difficulties revealed both temporal and spectral auditory processing deficits. This suggested that any auditory deficit associated with reading disabilities may be more complex than previously hypothesized.

Learners with a reading disability exhibit a deficit in the perception of auditory temporal cues in non-speech stimuli (Breier, Fletcher, Foorman, Klaas, and Gray, 2003:31). This is echoed by Heiervang, Stevenson, and Hugdahl (2002:931) who found that learners with dyslexia showed a general impairment in the processing of rapid auditory stimuli. Developmental dyslexia is associated with deficits in the processing of basic auditory stimuli (Witton, Stein, Stoodley, Rosner and Talcott, 2002:866). Facoetti, Lorusso, Galli and Molteni (2005:70) found that learners with developmental dyslexia have sluggish capture of both visual and auditory input.

At the beginning of reading acquisition, learners learn via the phonological route. Auditory spatial attention is linked to phonetic perceptual processing as well as to phonological short-term memory. Because the processing of sensory input in these learners is too slow, incoming information accumulates and floods the system. This leads to confusion and a loss of attention control (Facoetti et al, 2005:70).

Learners with reading difficulties have a domain-general deficit in processing rapidly occurring auditory stimuli which limits phonological awareness (Waber, Weiler, Wolff, Bellinger, Marcus, Ariel, Forbes and Wypij, 2001:37). Learners with specific reading disabilities have deficits in processing rapidly presented non-speech auditory signals. Deficits that occur in the brainstem affect understanding and integrating of the auditory context (Cohen-Mimran & Sapir, 2007:175).

The different research results indicate that the tempo of recognition and processing of auditory input are very important for the learner to obtain attention control. As can be seen from the research mentioned above, the brainstem is very important for attention control and for working memory. This neural area could be the source of developmental dyslexia and it might be that the same intervention that helped for attention control may also eliminate dyslexia (Chandrasekaran, Hornickel, Skoe, Nicol and Kraus, 2009:311).

Research done by Sturm, de Simone, Krause, Specht, Hesselmann, Radermacher and Herz (1999:803) showed that there is evidence for a fronto-parietal-thalamic-brainstem network in the right hemisphere. In the brainstem the ponto-mesencephalic tegmentum and locus coeruleus are most probably involved.

3.4.3 Cochlear Nucleus

(cf. Annexure L – Figure 3.10)

According to Hawkins (2008:17) the **cochlear nucleus** appears to be capable of making the extraordinary fine discriminations of time and intensity that are necessary for sound localization. The two ears are much more effective than one ear alone in picking out a particular sound in the presence of a background of noise. They also permit attention to be directed to a single source of sound, such as one instrument in an orchestra, or listening to the teacher's voice when there are background noises in the classroom. A listener with normal hearing can attend to different conversations in turn or concentrate on one speaker despite the surrounding babble (Hawkins, 2008:17).

Most of the fibres of the cochlear nucleus project to the superior olivary complex. The superior olivary complex, located in the pons, controls the reflex activity of the tensor tympani and stapedius muscles of the middle ear. This explains the contraction of the stapedius muscles in both middle ears when sound is presented to just one ear (Martin, 1998:118).

The medial geniculate body, located in the thalamus, is the last subcortical relay station for auditory impulses. After this point, nerve fibres fan out as the auditory radiations and then ascend to the auditory cortex (Hawkins, 2008:17). If there are lesions in either the medial or the lateral caudate-putamen, sustained deficits in the auditory conditional response will be the result (Adams, Kesner and Ragozzino, 2001:106).

3.4.4. Reticular Activating System

(cf. Annexure L – Figure 3.11)

The reticular activating system resides in the centre of the brainstem and communicates with virtually all areas of the brain, including the cortex and the spinal cord. Snell (2001:304) found that the reticular formation resembles a net that is made up of nerve cells and nerve fibres. It plays a major role in auditory alertness, reflexes and habituation. According to Ayers (1972), the reticular activating system helps the brain focus on one sensory input or type of sensory input by inhibiting other types of sensory input. This system may be the primary control centre for the central nervous system (Snell, 2001:304).

Sugarman (2003:258) states that the threshold for reacting to environmental stimulation varies strongly with the background state of wakefulness, from deep sleep to hyper-alertness. Individuals react differently to incoming sensory stimulation. The scale between these two extremes is called the level of alertness, which may be defined as a generalized state of receptivity to stimulation and preparedness to respond. Alertness defined in this way refers to the normal states of consciousness and to the ability to pay voluntary attention (Sugarman, 2003:258).

The ascending reticular activating system (ARAS) consists of the reticular formation plus non-specific afferents that ascend through the intralaminar nuclei of the thalamus, and then fan out to various parts of the brain, particularly the cortex (Sugarman, 2003:206). An important branch of the afferents turns away, to enter the hypothalamus. This provides a link between alertness and viscer-autonomic phenomena (Sugarman, 2003:260). The ARAS plays a decisive role in activating the cortex by regulating the state of its activity. The activity of the system itself is mainly determined by sensory input. The system is also responsible for the maintenance of alertness and is thus very important when looking at attention problems (SAIT, 1995:2).

The unpredictable, modulated music used in Berard AIT (cf. 4.5) is likely to stimulate a particular area of the reticular activating system which is activated by novel sensory input.

Moreover, there are interconnections between the reticular formation (important in attention processes and sustaining arousal) and the vestibular nuclei. The unique sounds produced in the Audiokinetron and the Earducator (Brockett, 2003:23) during Berard AIT (cf. 4.5) training may be stimulating the vestibular-cerebellum-frontal lobe connection, producing changes not only in the auditory processing of sound, but also in posture, balance and spatial orientation. Excitation spreads over the net of this neural structure gradually, changing its level of activity little by little (Berard in SAIT, 1995:2).

The efficient functioning of the reticular activating system also depends heavily on the neurotransmitter norepinephrine, which plays a role in alertness, motivation, emotion and arousal. The temporary periods of irritability and hyperactivity that are sometimes seen during or directly after Berard AIT (cf. 4.5) may relate to a temporary increase in norepinephrine production (SAIT, 1995:2).

Stephen Edelson (in SAIT, 1995:2) commented on the eventual calming effect of music and found that one of the most frequently reported changes as a result of Berard AIT (cf. 4.5) is an overall calmness in the listener. This is reported by parents as well as by people who participated in Berard AIT listening sessions. A better

sleeping pattern, an increase in attention span, a decrease in anxiety and a decrease in hyperactivity after the training may be indicative of the calming effect of Berard AIT(cf . 4.5) (Stehli, 2004:3).

“Music soothes the savage beast” (SAIT, 2001:2). Individuals who are hypersensitive to sound are often in an anxiety state because of an activated Moro reflex (cf. 1.4.5) system, the modulation inherent in the Berard AIT (cf. 4.5) music seems to calm down the person’s arousal system. When the reticular activating system is calmed down by more inhibitory neurons, a person is better able to pay attention and to learn (SAIT, 1995:2).

3.5. Cerebral cortex

(cf. Annexure L – Figure 3.12)

The cerebral cortex itself serves as a source of input for the brainstem reticular formation as a regulator of the level of attention (Lindsay & Bone, 2002:200). The cortex is the final analyser of signals that are or are not attended to and the cortex supplies a representation of the outside world for localizing novel stimuli that provoke arousal. The role of the cortex as activator is largely dependent on a number of connections forming the descending activating system. In many respects the descending system is the mirror image of the ascending system (Lindsay & Bone, 2002:200).

3.5.1. The Temporal Lobes

(cf. Annexure L – Figure 3.13)

Wernicke’s area permits the understanding of the written and spoken language and enables a person to read a sentence, understand it, and say it out loud (Snell, 2001:287). This sensory speech area of Wernicke is localized in the left dominant hemisphere, mainly in the superior temporal gyrus, with extensions around the posterior end of the lateral sulcus into the parietal region. Wernicke’s area is connected to Broca’s area, which is situated in the frontal area of the left hemisphere, by a bundle of nerve fibres called the arcuate fasciculus. It receives fibres from the

visual cortex in the occipital lobe and the auditory cortex in the superior temporal gyrus (Snell, 2001:287).

The meaning of sounds is interpreted and behaviour is adjusted in accordance with their significance at the cortical level. Such functions were formerly attributed to an “auditory association area” immediately surrounding the primary auditory area, but we know that they involve much more of the cerebral cortex, thanks to the multiple, parallel interconnections between the various areas (Hawkins, 2008:18).

Research done by Moncrieff, Jerger, Wambacq, Greenwald and Black (2004:518) shows, that learners with poor left hemisphere processing experienced the following deficits:

- Slowed neural conduction times;
- Poor interhemispheric transfer of neural activity; and
- Failure to suppress competing information which arrives at the right ear.

Moncrieff, et al (2004:518) affirms that these above mentioned problems will present as attention deficits.

3.5.1.1. Arousal or the orienting reaction

(cf. Annexure L – Figure 3.14)

According to Ratey (2002:115) an elementary attention mechanism is the sudden increase in alertness known as arousal. It is also often referred to as the orientating reaction or arousal reaction. It is controlled by two reciprocal systems that converge on the amygdala. This almond shaped nucleus in the pole of the temporal lobe is part of the limbic system and might thus supply the emotional tone of arousal. Both systems originate in the frontal cortex, converge on the amygdala, and finally influence hypothalamic structures related to arousal (Ratey, 2002:115).

Pavlov (1927) described a reflex that apparently enables animals to attend to novel and possible biological important stimuli. He noticed that a previously conditioned response failed to occur in a dog if an unusual stimulus – e.g. a stranger entering the experimental area, was attended to by the animal. This attention to a novel stimulus was termed the ‘orienting’ or ‘what is it?’ reflex. The same reaction also occurs with

children in a classroom when the door opens and a person enters the room (Levitin, 2006:185).

3.5.2. Descending Pathways

(cf. Annexure L – Figure 3.15)

Rasmussen (in Lalaki, 2005:1) had shown in 1960 and 1964 that in addition to the afferent pathways, the auditory system contains a complex efferent system of descending fibres. One of the functions of the descending system is to provide inhibitory feedback, while some descending connections also have an excitatory function (Strait, Kraus, Parbery-Clark and Ashley, 2009:22; Martin, 2001:118).

Lalaki (2005:10) states that the efferent impulses may determine which ascending impulses are to be blocked and which are allowed to pass on to higher centres of the brain. It is believed that these fibres serve as a feedback mechanism and inhibit the reception of sound (Lalaki, 2005:10). They may also have a role in the process of auditory sharpening, suppressing some signals and enhancing others (Snell, 2001:119). It has been suggested that the stimulating music of Berard AIT (cf. 4.5) activates these descending fibres in a way that increases their suppressing role, and that this is the method through which hypersensitivity to sounds disappear (Brockett, 2006:14).

Hawkins (2008:13) asserts that by virtue of the bilateral neural interconnections in the brainstem, the two ears together can be much more effective than one ear alone, in picking out a particular sound in the presence of a background noise. They also permit attention to be directed to a single source of sound, such as one instrument in an orchestra or one voice in a crowd. A listener with normal hearing can attend to different conversations in turn or concentrate on one speaker despite the surrounding babble. This ability is often lacking in learners with auditory processing problems (Hawkins, 2008:13).

As Berard AIT (cf . 4.5) is thought to eliminate auditory processing problems in most cases, the music most probably stimulates the cochlear nucleus (Hawkins, 2008:13). It has not been determined whether the muscles within the ear play a part in filtering out

unwanted sounds during selective listening. One of the theories of the success of AIT in eliminating auditory processing problems, is due to the effective working of the sensor tympani and stapedius muscles. The auditory training stimulates the muscles to work in unison and to react effectively to sound stimulation. This will increase auditory input with an increase in alertness and in attention (SAIT, 1995:3).

3.5.3. The Cerebellum

(cf. Annexure L – Figure 3.16)

The cerebellum (literally meaning “little brain”) is located in the hindbrain under the occipital lobes and is mainly responsible for coordination, finer muscular movements and timing (Demos, 2002:56). Balance is controlled by the cerebellum and the vestibular systems. The two lobes of the cerebellum are connected homolaterally to the body. Working in conjunction with the sensory motor strip of the cerebral cortex, the cerebellum helps the individual to carry out voluntary muscle movements. Although the cerebellum weighs only ten percent of the weight of the whole brain, it contains 50% to 80% of the total number of neurons (Levitin, 2006:170).

The frontal lobes are connected directly to the cerebellum. The connections run in both directions, with each structure influencing the other (Snell, 2001:118). The cerebellum is also involved in emotions and it also controls a person’s ability to sing a song from memory. The emotional response to music occurs via the ear-cerebellum-nucleus accumbens – limbic circuit rather than via the ear-auditory cortex circuit. Thus the brain’s response to music is all via connections (Snell, 2001:118).

According to Brockett (2003:34) the cerebellum controls finer movements of the body. Movements made by most animals have a repetitive quality. When we walk, run or skip, we tend to do it at a constant pace and the body settles into a gait and maintains it with the help of the cerebellum. The function of this oldest part of the brain is something that is crucial to music, namely ‘timing’. Anecdotal evidence relates that Berard AIT (cf. 4.5) leads to an improvement in balance problems, as well as an improvement in several sport activities such as tennis, karate and soccer, where precision of specific movements are necessary. A knock-on effect of effortless physical

control is that the learner will have more energy available to pay attention to incoming stimuli (Brockett, 2003:34).

3.5.3.1. Music and the cerebellum

Levitin, together with Vinod Menon and Ursula (in Levitin, 2006:180) found that the inferior and orbital areas of the frontal lobes are stimulated during the processing of language and music. Strong activation is found in the brain when people listen to music but not when they listen to noise. The cerebellum appears to be involved in tracking the beat. Schmahmann (in Levitin, 2006:171), a Harvard professor, and his students, found that the cerebellum is involved in emotion. This would account for the activation that occurs when people listen to music that they like. The cerebellum contains massive connections to emotional centres of the brain (Levitin, 2006:171).

Reports following Berard Auditory Integration Training (cf. 4.5) mention a calming down in the emotional distress that some learners experienced prior to the intervention. In the book, *The Sound of a Miracle* (Stehli, 1995:160), Annabel Stehli describes how her daughter Georgie, who was thought to be psychotic and retarded as an eleven year old, calmed down and was teachable after she was trained in the Berard AIT (cf. 4.5) method (Stehli, 1995:160).

Of particular interest to this study, Schmahmann (in Levitin, 2006:144) rediscovered a paper from 1934 suggesting that the cerebellum was involved in the modulation of arousal, attention, and sleep. Additionally, during the 1970's research showed that lesions in, or stimulation of parts of the cerebellum could cause dramatic changes in arousal (Levitin, 2006:183). Anecdotes (Stehli, 1995) reported that there was a clear change in arousal and attention after Berard AIT (cf. 4.5), but the principle why this would occur was unknown.

It used to be believed that the only brain area connected to the inner ear was the auditory cortex and that this connection was processed via the brainstem (Levitin, 2006:180). However, neurologists had already in the 1970's presented research which showed that there are direct connections from the inner ear to the cerebellum. The research also revealed that neurons, which are location-, balance- and position-

sensitive, are present in the cerebellum. Our sense of position in space is thus not only present in the vestibular system but also in the cerebellum and the interplay between the inner ear and the hindbrain. It is therefore plausible that the more the learner is centred and comfortable in his or her body, the easier it would be to pay attention to external incoming signals (Levitin, 2006:180).

3.5.4. Frontal cortex

(cf. Annexure L – Figure 3.17)

The first of these systems has its cortical component in the dorsolateral frontal cortex, and has a facilitating affect on arousal (Sugarman, 2003:259). The second system originates in the orbital-frontal cortex and represents an extensive inhibitory pathway. This reciprocal innovation allows the sensitive modulation of the arousal mechanism. The hippocampus also plays an important role in the arousal reaction. Since this area is essential for storage of information, it has a key role in distinguishing between old and new stimuli (Sugarman, 2003:259).

If a mismatch between stimulus and the model contained in the brain occurs, the stimulus is considered novel and the hippocampus activates the reticular formation, resulting in arousal. Habituation, also known as negative adaptation, keeps any source of information from alerting us continually which would make goal-directed behaviour impossible (Ratey, 2002:116). With symptom augmentation, where there is little inhibition on the constant influx of sensory information, this habituation is not fully functional. This may be where Berard AIT (cf. 4.5) could have a major effect in calming hyper-alert and hyper-mobile learners (Stehli, 1995:161).

3.6. Music stimulation

Levitin (2006:86) found that the cochlear nuclei, brain stem and cerebellum were activated during music stimulation, well before the auditory cortices received the impulses. The cochlear nuclei, the brain stem, and the cerebellum are first activated and then the stimuli move up to the auditory cortices in both hemispheres. Similarly, research done by Brockett (SAIT, 2002:7) showed that Berard AIT (cf. 4.5) stimulates the cerebellum through the vestibular-cerebellum connection. If a person is listening to familiar music, the hippocampus, the focus of the memory centre, as well as the

inferior frontal cortex, are stimulated. Furthermore, moving and dancing to music involves the timing circuits of the cerebellum. When you also sing along to the music Broca's and Wernicke's language regions, as well as areas in the temporal and frontal lobes will be activated (Levitin, 2006:86).

According to Wang, Nicol, Skoe, Sams and Kraus (2009:1), there is evidence of attention and sound processing in the auditory nerve and in the brainstem. When a threatening sound is heard, the emotional effect can be recorded 20 milliseconds after the stimulus. When the sound is non-threatening, the emotional response is within 30 to 130 ms, and occurs in the brainstem. Early processing of auditory stimuli were thought to be unaffected by attention, arousal and language memory, but in the last decade it has been shown that auditory responses are not immune to non-auditory influences (Wang, Nicol, Skoe, Sams and Kraus, 2009:1).

Levitin (2006:87) declares that music processing is in some ways the same as analysing other sounds. Understanding speech requires that a flurry of sounds be categorized into words, sentences and phrases and accompanying emotions must be understood. Similarly, several different dimensions of a musical sound need to be analysed and brought together to form a coherent representation of what is being listened to. The brain is a parallel processing device, with operations distributed widely throughout. There is no single language centre, nor is there a single music centre. There are rather regions that perform component operations, and other operations that coordinate the synthesis of this information (Levitin, 2006:87).

Much of the brain's power comes from the enormous potential created by interconnections. The brain can work on many things at once, overlapping and in parallel (Levitin, 2006:87). The auditory system processes different aspects of sound at the same time – it does not have to wait to find out what the pitch of a sound is to know where it is coming from; the neural circuits for these two operations generate the answers to these two questions concurrently (Levitin, 2006:87).

A re-training of the auditory system, such as with the Berard Auditory Integration Training (cf. 4.5), is thought to speed up and synchronize the information being processed in different brain regions. The result may be a faster and more efficient

processing time and better comprehension of what has been said. This will have a direct influence on the learner's ability to pay sustained attention to material presented in the classroom (Personal conversation with Brockett, 2006).

3.7. Music sounds

3.7.1. What happens in the 'mind' when a sound is heard?

According to Levitin (2006:185) the goal in attempting to understand the influence of music on the 'mind' is to understand thought processes, memories, emotions, and experiences and to understand how the activation of the brain in specific ways can alter the functioning of these very specific functions. The frontal lobe, the centre of the most advanced cognitions in humans, is connected directly to the cerebellum, the most primitive part of the human brain. The connections run in both directions, with each structure influencing the other. Regions in the frontal cortex, those that help us to distinguish precise differences in speech sounds, are also connected to the cerebellum. Ivry's (in Levitin, 2006:189) research on motor control showed connections between the frontal lobes, occipital cortex, the motor strip, and the cerebellum.

Levitin (2006:191) postulates that music stimulates the different brain regions analogous to the coordinated sounds created by an orchestra. The oldest part of the brain, the brain stem, and the newest parts of the human brain, the cortex, and regions as far apart as the cerebellum in the back of the head and the frontal lobes just behind the eyes, becomes active when music is heard.

Music appears to mimic some of the features of language and to convey some of the same emotions that verbal communication does (Levitin, 2006:189). Levitin (2006:189) found that music also activates some of the same neural regions that language does, but far more than language, music taps into primitive brain structures involved with motivation, reward and emotion. These features are very important in the motivation of a learner to pay attention to auditory stimulation. With Berard AIT (cf. 4.5) the beat of the music gets interrupted at a random and in an unpredicted way. This will lead to an emotional response which occurs via the ear-cerebellum-nucleus accumbens – limbic circuit rather than via the ear-auditory cortex circuit. As the response goes through the

cerebellum rather than the frontal lobes, it is largely pre-cognitive or unconscious (Levitin, 2006:189).

In 1999, Anne Blood (Levitin, 2006:185) had shown that intense musically-activated emotion was associated with brain regions thought to be involved in reward, motivation, and arousal: the ventral striatum, the amygdala, the midbrain, and regions in the frontal cortex. These are regions that will directly influence the learner's attention. The ventral striatum includes the nucleus accumbens, which is the centre of the brain's reward system, playing an important role in pleasure and addiction. It releases the neurotransmitter dopamine. If a learning experience is rewarded by a pleasurable emotion, it will be repeated (Levitin, 2006:185).

Listening to music causes a cascade of brain regions to become activated in a particular order:

- auditory cortex for the initial processing of the components of the sound;
- frontal regions, involved in processing musical structure;
- mesolimbic system, which is involved in arousal, pleasure, and the transmission of opioids;
- nucleus accumbens for the production of dopamine; and
- the basal ganglia were active throughout, presumably supporting the processing of rhythm and meter (timing) (Levitin, 2006:185-187).

Jaap Panksepp (1995) found growing evidence that some individuals on the autistic spectrum have elevated levels of brain opioid activity. These elevated levels of brain opioids, such as beta-endorphins, which are endogenous opiate-like substances in the brain, are associated with either pleasurable or anaesthetic effects. Substances occurring in natural food to which the learner might be sensitive/allergic can cause the mind to become addicted to the substance. This will have a suppressing influence on neuro-activation with a resulting loss of focus (in SAIT, 1995:2).

The beta-endorphin hypothesis of Berard AIT (cf . 4.5) suggests that the modulated music stimulates, and possibly normalizes, areas in the brain which release endogenous opioids. According to Panksepp (1995) it is established that listening to music activates endogenous opioid. One possible area in the brain involved in the

release of beta-endorphins is the inferior colliculus of the midbrain which receives sound input and is rich in opioid receptors. Panksepp hypothesized that as the brain function normalizes the learner will be able to obtain optimal concentration, attention and functioning (SAIT, 1995:2).

To test this hypothesis, Panksepp and his colleagues, Rossi & Narayanan (SAIT, 1995:2), exposed groups of newborn chicks to AIT music (modulated by the Audiokinetron system), non-AIT music (unmodulated music) and non-music conditions. Chicks were used because their hearing apparatus is similar to that of humans. Music conditions, both AIT and non-AIT were found to increase levels of 5-hydroxyindolacetic acid (5-HIAA) and norepinephrine, which are intimately involved in attention processing (Edelson, Arin, Bauman and Rimland, 1999:75). The results show that music might influence concentration positively, but it does not show Panksepp's hypothesis to be true.

In 1960, Linsey (in Andreassi, 2000:479) found that attention is closely linked to arousal and wakefulness. Like wakefulness and consciousness, attention appears to be a graded phenomenon extending from general alerting, as in becoming aware of the stimulus, to specific alerting, when attention is focused upon and dominates a given sensory input to the point of exclusion of other sensory stimuli. A learner unable to pay attention to a task will perform badly on almost any other test. Learning and memory tasks may be particularly affected by attention deficits (Martin, 1998:202).

3.8. Dyslexia

Berard AIT (cf. 4.5) has been claimed by an anecdotal report to alleviate the symptoms of dyslexia (Gaab, 2007:2). Gaab (2007:2) did a study with colleagues to determine if there were different responses in fMRI (functional magnetic resonance imaging) images between learners without reading problems and learners who have been diagnosed with dyslexia. The results indicated that the brains of children with dyslexia responded similarly to fast and to slow changing sounds. The same brain regions responded to both sets of stimuli. In contrast, the brains of typical children showed differences in 11 brain regions when listening to fast compared to slow sounds.

Learners with dyslexia show a general impairment in the processing of rapid auditory stimuli (Heiervang, Stevenson, and Hugdahl, 2002:931) as well as deficits in the processing of basic auditory stimuli (Witton, 2002:866). Temporal order judgment is also significantly poorer in dyslexics compared to controls (De Martino, Espesser, Rey, and Habib, 2001:104). Tallal (in Waber et al, 2001:37; and Cestnick & Jerger, 2000:501) hypothesized that reading disabled learners have a domain-general deficit in processing rapidly occurring auditory stimuli that degrades speech perception and limits phonological awareness and will have a severe detrimental effect on attention control. Moreover, Paula Tallal (Tallal & Gaab, 2006:385) had discovered, along with her collaborator Mike Merzenich of UC San Francisco, that dyslexia was related to a timing (latency) deficit in children's auditory systems. This has been verified by studies done by Davis (1994:43) and Phoenix (2002:5). It might be that the intensive auditory stimulation acquired during the ten days of Berard AIT (cf. 4.5), awakens the different brain regions in children with dyslexia and modulates latency (Berard, 1993:101).

Input from the different sensory systems, e.g. visual, auditory, kinesthetic, olfactory, proprioception and gustatory makes the individual aware of the external world. To achieve optimal functioning, information from these systems must form an effortless and fast communication system. The more effective the information loop, the easier it will be for the ever fluctuating attention to be focused.

3.9. Conclusion

The auditory system is an intricate communication system with connections across the different levels of brain functioning. Sounds, and especially musical sounds, stimulate the vestibular system; cerebellum system; the brainstem and several structures in the emotional centre of the brain. The primary and secondary auditory regions in the temporal lobes are activated as well as the pre-frontal regions. By using music as a primary means of stimulation and activation, the whole brain can be activated. This could create a balance between the inhibitory and excitatory neurons, which should result in increased calm and focused attention (Kropotov, 2009:235).

Auditory processing deficits are widely present in children with learning difficulties, but have been treated successfully in learners with reading and language disabilities

(McArthur, Ellis, Atkinson, and Coltheart, 2008:946). Kujala, Karma, Ceponiene, Belitz, Turkkila, Tervaniemi and Naatanen, (2001:10509) found that auditory training resulted in structural changes in the auditory cortex. This is possible because of the brain's plasticity. Faster reaction times and improvement in reading skills indicated that attention problems can be ameliorated by special training. If remedial interventions targeted at temporal resolution, is to be effective, early detection of the deficit and early application of the remedial programme is especially critical. If the learner is able to decode incoming stimuli at a faster pace, the process will activate alertness and attention will improve (Hautus, Setchell, Waldie and Kirk, 2003:37).

In the following chapter the effect of poor listening skills will be discussed. Berard AIT (cf. 4.5) as an intervention will be addressed as well as the influence that this intervention might have on poor attention skills.