CHAPTER 1: INTRODUCTION AND PROBLEM STATEMENT

1.1 INTRODUCTION

It is a known fact that central auditory processing disorder[1] related problems are often seen to coincide with problems related to language disorder[2], sensory integration dysfunction[3] and learning disabilities[4]. In the clinical setting, overlapping occurs between central auditory processing disorders, language disorders, learning problems and sensory integration dysfunction. This phenomenon is accepted by most researchers in these fields (Rampp, 1980; Keith, 1984; Keith and Stromberg, 1985; Keith, 1988; Rees in Northern and Downs, 1991; Katz and Wilde, 1994; Gordon and Ward, 1995; Welsh, Welsh and Healy, 1996; McSporran, 1997; Cacace and McFarland, 1998; Chermak, 1998; Sloan, 1998; Bellis and Ferre, 1999; Chermak, Hall and Musiek, 1999) and as a result, the importance of teamwork, in working with these children, is recognised (Matkin and Hook, 1983; Young and Protti-Patterson, 1984; Sanger, Freed and Decker, 1985; Young, 1985; Koay, 1992; Chermak, 1998). However, there seems to be no unified holistic approach concerning both diagnosis and intervention in these areas. Different professionals working with children with central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction tend to look at these disorders from different perspectives. As a result, the intervention is often based on the insight of the particular professional. There is a need for a fundamental model that can unify approaches and schools of thought in the diagnosis and management of children

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[1] This term is defined and discussed in section 1.3.1
[2] This term is defined and discussed in section 1.3.2
[3] This term is defined and discussed in section 1.3.4
[4] This term is defined and discussed in section 1.3.3

with central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction.

In order to develop an integrated model, it is necessary to remember that the human mind cannot be divided into separate compartments and a human being has the ability to function holistically in a complex environment (Butler, 1983).

To ***clarify*** the need for a holistic view and approach to central auditory processing disorders, language disorders, learning disabilities and sensory integration it is necessary to look at the inter-sensory nature of learning development (Battin, 1988; Lewkowicz and Lickliter, 1994; Welsh, et al., 1996; Cacace and McFarland, 1998; Bellis and Ferre, 1999). Multi-modal perceptual testing and the integration of assessment results in a holistic manner enhances the integration of diagnosis and intervention of children with central auditory processing disorders, language disabilities, learning disabilities and sensory integration dysfunction. This study proposes an approach to the establishment of such a holistic approach to multi-modal testing and diagnosis.

In this chapter, the problem of the interrelationship between auditory processing disorders, language disorders, learning disabilities and sensory integration is discussed. The arguments will be based on literature in support of the clinical value of a holistic approach as well as on the teamwork of the professionals working with children with learning problems.

1.2 PROBLEM STATEMENT, RATIONALE AND OBJECTIVE OF THE STUDY

The aim of this section is to identify the problem in its context, to develop the rationale and to set the objectives for the study. This section highlights the need for a holistic and integrated approach to the management of children who experience difficulties related to the overlapping of central auditory processing disorder, language disorder, learning disability and sensory integration dysfunction. The problems caused by this need for an appropriate approach are put into the context. This context is the clinical setting where a child is in need of the intervention of various professionals, who deal with the above-mentioned pathologies.

The rationale for this study is rooted in the need for a more cost effective and efficient child-centred intervention strategy for children experiencing the group of pathologies under consideration. The objectives of the study as outlined in this section are to analyse some of the relevant literature in order to establish a theoretical baseline for management of the identified group of pathologies, to analyse overlapping patterns in the diagnostic assessment results obtained for a group of children in a school for remedial teaching, and to evaluate the extent to which the proposed theoretical baseline supports the experimental evidence of the patterns occurring in the population under investigation.

1.2.1 Problem statement

The problem statement indicates problems experienced in the clinical setting of managing children with problems in the group of pathologies under consideration, analysing these problems in the light of current thinking on this group of pathologies, and of suggesting possible solutions to these problems.

1.2.1.1 Typical clinical setting

In the clinical setting, it is often found that children with developmental learning problems benefit from concurrent intervention for learning disability (for example, from a remedial teacher), for central auditory processing disorder (for example, from an audiologist), for language disability (for example, from a speech- language pathologist), as well as for sensory integration dysfunction (for example, from an occupational therapist). From a clinical viewpoint, the question arises whether this type of intervention could be done more cost-effectively and efficiently and with greater benefit to the child if a holistic approach is used to integrate the different approaches of the various professionals.

The practical limitation to effective integration of the intervention strategy is most often experienced to be the inability of the different professionals to communicate effectively with each other in respect of measurement and diagnosis, intervention and prognosis of the extent of rehabilitation achieved. Work towards the integration of the principles of the various involved disciplines will alleviate this practical communication problem. Informal discussions with clinicians working in the field of learning disability, indicate that there might be an underlying fundamental central-nervous system dysfunction (or developmental lag in the central nervous system), which underlies this group of pathologies. An investigation into the possible integration of the different approaches of professionals will resolve this issue.

1.2.1.2 Relationship between learning disabilities, central auditory processing disorders, language disorders, and sensory integration dysfunction.

Within the context of the discipline of communication pathology the relationship between learning disabilities, central auditory processing disorders and language disorders has been known for decades, as is evident from, for example, Ayres (1983), Keith (1984), Bernstein and Stark (1985), Willeford (1985), Sanger, Decker and Freed (1987), Lynch, Eilers and Steffens (1992), Sanger, Keith, Deshayes and Stevens (1990), Gordon and Ward (1995), McFarland and Cacace (1995), Bench and Maule (1997), Cacace and McFarland (1998), and many other authors (outlined in the list of references in Appendix A). Authors which acknowledged the relationship between two or more of the disorders under investigation are outlined in the table in Appendix A.

Sensory integration theory and practice as established by the discipline of occupational therapy, and as outlined, for example, in Fisher and Murray (1991), also acknowledge the interrelationship between dysfunctions considered to be part of the occupational therapist's domain of sensory integration dysfunctions, and dysfunctions, such as dysfunction in praxis on verbal command, which are seen to be related to the area of central auditory processing disorders.

With regard to sensory inputs, it is known that information from the visual and auditory channels is integrated by the listener while perceiving speech (Kuhl and Meltzoff, 1982). This is true not only for normal speech perception but also applies to pathological situations. Findings of studies furthermore suggest that children at risk for communication disorders may have early difficulties in integrating auditory and visual information (Lynch, et al., 1992; McFarland and Cacace, 1995; Welsh, et al., 1996). It is noteworthy that Ayers (1983), as a leading sensory integration occupational therapist, found that children with a primary problem in the auditory-language domain and who received sensory integration therapy, showed markedly greater progress in reading tests than children who did not have sensory integration therapy. She also came to the conclusion that disorders in integration of sensory modalities, especially auditory, vestibular and somato-sensory stimuli, interfere with language development. The implication is that when evaluating a child with a learning disability, it must be determined whether or not the deficit is of a multi-sensory nature, as also noted by McFarland and Cacace (1995), Cacace and McFarland (1998), Sloan (1998), Bellis and Ferre (1999) and Chermak, et al., (1999).

The above-mentioned instances, where theorists and practitioners acknowledge the overlapping of the fields under consideration, point to a possible unifying theory and practice which could support a holistic approach to intervention for this group of pathologies.

1.2.1.3 Different models and perspectives of inter-sensory perception

A further contributory factor as pointed out by Lewkowicz and Lickliter (1994) is that, inter-sensory perception is an issue that had different models and perspectives in the past. Nicolosi, Harryman, and Kresheck (1989) *define **inter-sensory perception** as the neurological process of transferring sensory data received through one input modality to another system within the brain.* It is also referred to as cross-modality perception, inter-modal or inter-sensory transfer, transducing or supra-modal perception. Following the line of reasoning of Lewkowicz and Lickliter (1994) perceptual processing is not only stimulation, attention, learning, memory and emotions, but also comparisons between all the information received from one given sensation with the other sensations in order to make sense. The classical view of the mammalian brain (human and animal) sees the brain as a highly modular device in which sensory information is transmitted along parallel modalities in specific lines. These distinct sensory streams are then integrated in the association areas of the cortex, at the top of the hierarchy of brain function. During the fifties, Piaget (in Lewkowicz and Lickliter, 1994), advocating the modular view, saw the development of inter-sensory areas in the brain as slowly developing inter-modality mappings as a consequence of activity in the world. This basic concept is still accepted today. The current view of inter-sensory perception sees the modalities as separate and interacting with a continuous intermeshing of the senses (the Gibson model)(in Lewkowicz and Lickliter, 1994). It is believed that the human infant is sensitive to inter-sensory correspondences, even from the first hours of life. Current advances in neuro-physiological knowledge of the function of the brain prove that inter-sensory perception plays a very important role in learning right from the start of life (Gabbard, 1992; Bukatko and Daehler, 1995).

This model of inter-sensory perception, which, sees the modalities as separate but interacting, supports the view that an integrated model may be constructed from existing theoretical and assessment material.

1.2.1.4 Isolated approaches and lack of agreement in terminology and definition of central auditory processing

Despite the acknowledgement of the relationship between auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction and the multi-disciplinary team approach adopted in the clinical setting, the different disciplines still tend to treat auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction in an isolated manner (Cacace and McFarland, 1998). This may be due to the basic science adopted by the individual professionals. These isolated approaches and the lack of agreement in terminology and definition of central auditory processing become evident when one looks at the theoretical approaches of the diverse sciences concerned with children with learning developmental disorders in *Table 1.1.* This table shows the view and the corresponding theoretical approach of the basic science involved. The contents of this table originate from Graz (1998) who used Kamhi and Beasley (1985) as source, and is, for the purpose of this study, augmented with material from Nicolosi, et.al. (1989). The examples of the authors in the various fields have been added as part of this study, in order to ease contextualisation of the fields. A study of *Table 1.1* and the implications of this information points to the large body of scientific material available to create an integrated theoretical model in support of the holistic approach.

If one looks beyond the theoretical use of terminology and thought processes to explain the different approaches, as seen in *Table 1.1*, it is possible to use a combination of all these academic findings to develop an integrated approach incorporating most of the theories.

1.2.1.5 The syndrome view of developmental learning disorders

The foregoing issues regarding the multi-faceted way in which the group of pathologies under consideration is being viewed, points to concepts related to the management of a syndrome.

Table 1.1: Theoretical approaches of the basic sciences involved with children with learning developmental disorders, with particular emphasis on central auditory processing disorders:

View	Theoretical approach	Examples of Authors
Site of lesion	Assess, diagnose and manage the function of peripheral and central auditory pathways (Kahmi and Beasley, 1985).	Katz (1992) Musiek and Lamb (1994)
Psycholinguistic	Blends the disciplines of psychology and linguistics to analyse human behaviour with language function (Nicolosi, et al., 1989). Learning is comprised of several distinct processes that can be identified, assessed and managed in isolation (Kahmi and Beasley, 1985).	Koay (1992)
Neuro-psychological	Links brain and cognitive-linguistic functions. Sees learning disorders as surface manifestations of brain-based deficits or immaturity of some cognitive processes. Emphasis on diagnosis. View of most neurologists and neuro-psychologists (Kahmi and Beasley, 1985).	Kinsbourne (1993)
Behaviourist	View of the educationist concerned with methods to achieve academic performance. Concerned with the response rather than the problem (Nicolosi, et al., 1989) Measure and remediate incidents of observable behaviour (Kahmi and Beasley, 1985).	Hoffman (1983)
Nativist	Concerned with language as a central, maturationally defined mental function (Kahmi and Beasley, 1985). Experience is to activate innate capacity (Nicolosi, et al., 1989).	Chomsky (in Kahmi and Beasley, 1985 and Nelson, 1993)
Cognitive	Symbol and concept forming through knowledge acquired through assimilation and accommodation of environmental inputs and cognitive structures (Piagetian model)(Kahmi and Beasley, 1985).	Piaget (in Kahmi and Beasley, 1985 and Nelson, 1993)
Information processing	Cognitive science approach. Assessment, diagnosis and remediation focus on particular processing deficits (attention. memory and auditory processing)(Kahmi and Beasley, 1985). Involves both signal and higher-order processes (Young and Protti-Patterson, 1984).	Johnson-Laird (in Nelson, 1993), Butler, 1983 and Duncan and Katz, 1983 in (Young and Protti-Patterson, 1984).

(Sources: Young and Protti-Patterson, 1984; Kamhi and Beasley, 1985, Nicolosi, et al., 1989, Graz, 1998.)

The medical view of learning disabilities describes developmental learning disorders as a syndrome (Riccio, Hynd, Cohen, Hall, and Molt, 1994; Welsh, et al., 1996). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV, 1994: 771) "A syndrome is a grouping of symptoms, based on their frequent co-occurrence, that may suggest a common underlying pathogenesis, course, familial pattern, or treatment selection." The term "syndrome" is less specific than "disorder" or "disease" (DSM-III-R, 1987: 368). This approach leaves space and freedom to explore all possible conditions concerning all learning skills. In this approach learning disabilities are classified together with language disorders and motor skills disorders as a specific developmental disorder. Specific developmental disorder includes developmental reading disorder, developmental mathematics (arithmetic) disorder, developmental expressive writing disorder, developmental language disorder (expressive type and receptive type or mixed receptive-expressive type), developmental phonological (articulation) disorder, developmental co-ordination disorder and mixed specific developmental disorder (DSM-III-R, 1987; DSM-IV, 1994).

In using this syndrome approach, it seems logical to define central auditory processing disorder, language disability and sensory integration dysfunction as components of a learning disabilities syndrome. Viewing the group of pathologies under consideration as components of a syndrome supports the unification approach, where this unification attempts holistically to rationalise the knowledge of this syndrome.

1.2.1.6 An integrated approach in the clinical setting

The disagreement between different disciplines and sciences and associated isolated approaches to children with learning developmental disorders is not the only factor hindering an integrated approach. The problem can also be ascribed to the clinical setting (which can be observed in diagnosis and therapy in practice) where the general approach is not a holistic approach, but an isolated one in which professionals work individually. In the training of communication pathologists in South Africa different professional approaches are acknowledged. Students do get the opportunity to observe the therapy of other professionals, but training in a holistically integrated approach to assessment and intervention is limited.

1.2.1.7 Teamwork

In the clinical setting, a holistic approach can be achieved through the establishment of diagnostic and therapeutic teams.

Working in a team is widely accepted and recommended by various professionals who work with children with developmental learning disorders and central auditory processing disorders (Matkin and Hook, 1983; Young, 1983; Young and Protti- Patterson, 1984; Keith and Stromberg, 1985; Sanger, et al., 1985; Young, 1985; Sanger, et al., 1987; Cline, 1988; Koay, 1992; Riccio, et al., 1994; ASHA, 1996 and Bellis, 1996, DeConde Johnson, Benson, and Seaton 1997; Sloan, 1998; Chermak, et al., 1999). A team is a group of professionals selected to work with a specific child/children and their parents. Interaction takes place between these individuals to determine an outcome (Du Plessis, 1998). With reference to the work of Du Plessis (1998) three models of teamwork can be identified, namely:

- multi-disciplinary teamwork, where each team member takes responsibility for activities related to his discipline;

- inter-disciplinary teamwork, where team members work together towards a common goal;
- trans-disciplinary teamwork, where one person, under the supervision of professionals of other disciplines, renders the service.

It is clear from the above description of different teams, that not all teams will necessarily achieve a holistic approach. The inter- and trans-disciplinary teams seem to be the teams that could function in such a holistic manner.

According to the literature the team generally suggested for the management of children with central auditory processing disorders should consist of the speech- language pathologist, audiologist, educational psychologist, remedial teacher, occupational therapist, neurologist and ear- nose-and-throat specialist, class-teacher, social worker and parents (Keith and Stromberg, 1985). Regardless of the model of teamwork used in the clinical setting, a more unified holistic approach towards diagnosis and intervention could provide a more effective way of managing children in the areas under consideration.

1.2.2 Rationale underlying the study

Based upon the above discussion of the problem statement the following hypotheses can be formulated:

- it is possible to view learning disability as comprising of elements such as central auditory processing disorder problems; as elements in a developmental learning syndrome consisting of the elements of language disorders, learning disabilities and sensory integration dysfunction,

- it is possible to develop an integrating holistic model of evaluation and intervention, which underlies the above-mentioned developmental learning syndrome.
- it is possible to base the diagnosis for this disorder upon the above-mentioned unifying holistic model,
- an unifying holistic intervention strategy based upon the current therapeutic practices and using the above-mentioned model, can be the preferred intervention strategy for children with this developmental learning syndrome.

One of the ways in which to approach the above hypotheses is to ask whether or not the conventional assessments currently used in schools for children with learning disabilities can be used in such a way that they will assist in approaching these children in a holistic way incorporating and even promoting the trans-disciplinary team approach? The aim of the study is therefore to present assessment results obtained by the conventional evaluation of the children at a school for remedial teaching in such a manner as to facilitate effective diagnosis and intervention on the basis of a unifying holistic model. The different professionals can be made more aware of co-existing problems to make intervention more effective and for the early identification of problems.

The problem will be addressed by a theoretical study of literature concerning the comorbidity of central auditory processing disorders, language disability, learning disabilities and sensory integration and a critical evaluation of the assessment results used at a school for remedial teaching.

1.3 DISCUSSION OF TERMINOLOGY

In this study where different approaches to related disorders are investigated, it is possible to get embroiled in the disputes over definitions and terminology used to describe central auditory processing disorders, language delay, learning disabilities, sensory integration dysfunction and other developmental disorders. Different professional perspectives of audiologists, speech- language pathologists, educationists, occupational therapists and medical professionals lead to diverse approaches, emphases on different aspects and development of evaluation tools and remedial strategies (Stach and Loiselle, 1993; Lasky and Katz, 1983).

Without getting embroiled in terminology and different approaches, a brief description will be presented to form the basis of this study.

1.3.1. Central Auditory Processing Disorders

The American Speech-Language-Hearing Association (ASHA) makes a very relevant observation (ASHA, 1996: 42): “After more than 20 years of dealing with issues related to central auditory processing, ASHA still lacks statements of consensus on definition, identification procedures, or intervention practices. Controversy persists over central auditory processing and its disorders, and how it should be defined, identified, and ameliorated through intervention.”

It is clear that consensus on the definition is difficult to reach (Sanger, et al., 1990; Katz, 1992; Stach and Loiselle, 1993; McFarland and Cacace, 1995; ASHA, 1996; Cacace and McFarland, 1998; Sloan, 1998). This lack of agreement results in a myriad of definitions of auditory processing. The Task Force on Central Auditory Processing Consensus Development of ASHA in 1996 tried to remedy this problem and came up with the following definition (ASHA, 1996: 43):

"Central auditory processes are the auditory system mechanisms and processes responsible for the following behavioural phenomena:

- Sound localisation and lateralisation
- Auditory discrimination
- Auditory pattern recognition
- Temporal aspects of audition
- Auditory performance decrements with competing acoustic signals
- Auditory performance decrements with degraded acoustic signals."

"A central auditory processing disorder is an observed deficiency in one or more of the above-listed behaviours." This is a very broad definition which attempts to accommodate a number of professional views. Criticism is that this definition is too vague and complex and the components are not clearly defined. The definition also does not address two divergent approaches to central auditory processing, namely, that of the audiologist and the speech-language pathologist (DeConde Johnson, et al., 1997; Cacace and McFarland, 1998).

This situation is further complicated by the lack of agreement on the most appropriate *term* for the function or dysfunction of the central nervous system involving audition (Lasky and Katz; 1983; Pinheiro and Musiek, 1985; Cline, 1988; Sanger, et al., 1990; Koay, 1992; Campbell, 1994). The term *central auditory processing* is generally used to refer to the use made of the auditory signal. Central auditory processing is the most commonly used term for this process in literature of the last decade (Katz and Wilde, 1994; Cline, 1988; Katz, 1992). The importance of this term is that it focuses attention on the role played by the central auditory nervous system (the nervous system from the cochlear nucleus of the brainstem to the cortical temporal lobe of each hemisphere of the brain)(Kaplan, Gladstone and Katz, 1984; Young, 1985). Central auditory processing is not only perception of sound, but also how we explain, localise, attend to, analyse, store and recall the auditory information. It is about how we implement the knowledge to understand the message and how to integrate the associated auditory information with visual and other sensory insets (Young, 1985; Perkins and Kent, 1986; Katz and Wilde, 1994).

The term ***auditory processing***, omitting the word central, implies that auditory processing involves more than the central system. The proper functioning of the peripheral mechanisms are indeed of great importance in the processing of a message. The term *auditory perception* is a parallel to the term *visual perception* and is understood by the public as well as professionals, but it is used by relatively few professionals at this time (Katz, Stecker, and Henderson, 1992, Campbell, 1993; Katz and Wilde, 1994). Koay (1992) describes auditory perception as the ability to process information through the auditory modality. The use of the word *processing* as *opposed* to perception refers to an individual's response to an auditory stimulus rather than to the stimulus itself (Katz and Wilde, 1994). For example, one clinician will use *auditory perception* and *auditory processing* synonymously whereas another will differentiate between them as different functions (Koay, 1992). In the same context variations exist in what clinicians consider to be essential perceptual "sub-skills" of auditory processing, and where the same term or sub-skill may be used differently (Keith, 1988, Koay, 1992). This confusion in the use of terms can be due to the complex nature of central auditory processing and the resulting different professional views (Young, 1985; Musiek, Gollegly, Lamb and Lamb, 1990;

Katz and Wilde, 1994). Different perspectives in the context of auditory processing as seen in the literature (Young and Protti-Patterson, 1984; Kamhi and Beasley, 1985; Keith, 1988, Koay, 1992; Campbell, 1994) that influence current thinking about auditory processing and central auditory processing disorder, are the site-of-lesion, neuro-psychological, psychological, psycholinguistic and information processing perspectives (Kamhi and Beasley; 1985; Graz; 1998).

In the ASHA document of 1996, it is accepted that ***central auditory processing disorders*** are the result of dysfunction of processes and mechanisms dedicated to audition as well as the other point of view, namely, that central auditory processing disorders may stem from some more general dysfunction, such as an attention deficit or neural timing deficit, that affects performance across modalities.

When thinking of the clinical profile of an auditory perceptual disorder (a speech-language pathology term)(Young, 1985; Keith, 1988) or a central auditory processing disorder (an audiology term)(Young, 1985; Musiek and Chermak, 1994), clinicians, like the speech- language pathologist and audiologist, will have the same disorder in mind (Koay, 1992). The above terms and a variety of other synonymous terms are therefore used to describe similar communication deficiencies leading to a condition of confusion and misunderstanding.

There are at least two main approaches to central auditory processing disorders in the field of communication-pathology. The one is the linguistic school of thought held by the speech- language pathologist who sees central auditory processing as a linguistic dependent skill and looks at skills like auditory memory, auditory discrimination, auditory closure and auditory blending (Cline, 1988; Keith, 1988; Roeser and Downs, 1988;

Campbell, 1993; Campbell, 1994; Sloan, 1998). Central auditory processing is seen as a product of language and stresses the cognitive outlook of information processing. In this context Keith (1988: 84) defines central auditory processing disorders as "any breakdown in the child's auditory abilities that results in diminished learning through hearing, this is an inability to attend to, discriminate, recognise or comprehend information presented auditorially even though hearing sensitivity and intelligence is normal." The other approach is the auditory school of thought, where the audiologist is involved with the peripheral hearing and the intactness of the central auditory nervous system. It refers to the ability to understand distorted speech and to understand the primary speech message in a competitive situation (Keith, 1988; Smorski, Brunt and Tanahill, 1992; Stach, 1992; Campbell, 1993; Campbell, 1994; Bench and Maule, 1997). This approach incorporates the site-of-lesion and neuro-psychological approach and is of value within the medical profession to determine diagnosis (Kahmi and Beasley, 1985; Keith, 1988; Rees in Northern and Downs, 1991). Defining central auditory processing as a modality-specific perceptual dysfunction that is not due to a peripheral hearing loss endorses this approach (Jerger, Martin and Jerger, 1987; McFarland and Cacace, 1995; Cacace and McFarland, 1998; Jerger, 1998).

The above-mentioned two main approaches are combined by Campbell (1994) and McFarland and Cacace (1995) who consider auditory processing to be a collective term which encompasses both central auditory processing and linguistically dependent auditory processing skills. A child with an auditory processing disorder may therefore experience difficulty in both or only one of these areas (Campbell, 1994).

In South Africa the fortunate situation exists where students can be trained as both speech- language pathologists and audiologists and receive a degree in Communication

Pathology. A single professional is thus able to understand and incorporate both approaches in dealing with central auditory processing disorders.

The comprehensive definition compiled by the ASHA committee (ASHA, 1996) will be the one followed in this study. *It states that a central auditory processing disorder is a disorder in the processing of acoustic signals, which is not due to a peripheral hearing loss or mental inability and refers to deficiencies in continual transfer, analysis, organisation, change, processing, storing and use of information included in acoustic signals. It includes attention deficiencies and problems with memory, reading, spelling and written language.*

1.3.2 Language, language disorder and language processing

In this section the terms *language, language disorder* and *language processing* will be discussed, and the relevant definitions, which have proved most helpful to this research, have been stated.

"***Language is slippery to define***" (Nelson, 1993: 27). Therefore, the Committee on Language of the American Speech-Language-Hearing Association (in Nelson, 1993: 28; and in Owens, 1992: 335) proposed a broad definition of *language* as follows:
"Language is a complex and dynamic system of conventional symbols that is used in various modes for thought and communication. The contemporary view of human language holds that:

- Language evolves within specific historical, social and cultural contexts;
- Language, as rule governed behaviours, is described by at least five parameters – phonologic, morphologic, syntactic, semantic, and pragmatic;

- Language learning and use are determined by the interaction of biological, cognitive, psychosocial, and environmental factors;
- Effective use of language for communication requires a broad understanding of human interaction including such associated factors as non-verbal cues, motivation, and socio-cultural roles."

Important for this study is that language can thus be viewed as the abstraction of meaning from an acoustic signal and the retrieval of that meaning. Language is evaluated in terms of comprehension and expression of oral language (Butler, 1983). Language is "a vehicle for communication" (Owens, 1995, p 4). It is "a social tool" and a dynamic process rather than a product (Owens, 1995, p 4). In learning to speak and understand language, a child learns how to relate sound and meaning. It is however not a simple matter of learning words and their meaning but it must go further to consider the context in which these words are used (Sloan, 1992).

A ***language disorder*** (according to Nicolosi, et al., 1989: 152) can be described as follows:

"(a) Any difficulty with the production and/or reception of linguistic units, regardless of environment, which may range from total absence of speech to minor variance with syntax; meaningful language use may be produced, but with limited content; e.g., reduced vocabulary; restricted verbal formulations; omission of articles, prepositions, tense and plural markers; paucity of modifiers.

(b) Inability or limited ability to utilise linguistic symbols for communication.

(c) Any interference with the ability to communicate effectively in any community as dictated by the norms of that community."

The definition used by Owens (1992), namely, that language can be seen as a socially shared code where a conventional system of arbitrary symbols is used to represent concepts that are meaningful to others using the same code, will be used to describe language in this study. This definition is chosen because it forms a logical framework for the definition of language impairment.

Children who are *language impaired* are characterised as having significant deficits in production and comprehension of language, yet have normal non-verbal intelligence. They have normal hearing and are within normal limits in behavioural and emotional development (Bernstein and Stark, 1985; Helzer, Champlin and Gillam, 1996). They exhibit limitations in language functioning without obvious neurological, cognitive, sensory and/or motor deficits (Cacace and McFarland, 1998).

The term *language disorder* or *disability* can be used as a synonym for deviant language or language impairment. In contrast to language *disorder*, language *delay* can be described as the failure to comprehend and/or produce language at the appropriate age (Nicolosi, et al., 1989).

Language processing can be defined as the abstraction of meaning from an acoustic signal or from printed text (Butler, 1983). It is the process of hearing, discriminating, assigning significance to, and interpreting spoken words, phrases, clauses, sentences and discourse (Nicolosi, et al., 1989). Language processing is considered a psychological process within an information processing model (Butler, 1983). What is added here is the attempt to analyse language as a series of intertwined events to identify, extract and utilise linguistic information. Language is now analysed by looking at skills like attention, perception, memory and auditory processing as related to the use of language (Butler, 1983). The concepts of language processing and central auditory processing thus overlap.

1.3.3 Learning Disability

Many definitions of learning disabilities have been proposed and there are many disorders under the learning disability umbrella. People who have a learning disability vary widely, depending in the definition used by the specific professional consulted (Owens, 1984). In this discussion, the definition which best reflects the rationale of the study will be presented.

A ***learning disability*** (according to Nicolosi, et al., 1989: 152) can be described as:
"(a) a 'Specific learning disability' means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, think, speak, read, write, spell or to do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia and developmental aphasia. The term does not include children who have learning problems which are primarily the result of visual, hearing or motor handicaps, of mental retardation, of emotional disturbance, or of environmental, cultural or economic disadvantage.
(b) a Generic term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual and are presumed to be due to central nervous system dysfunction. Even though a learning disability may occur concomitantly with other handicapping conditions (e.g., sensory

impairment, mental retardation, social and emotional disturbance) or environmental influences (e.g., cultural differences, insufficient/inappropriate instruction, psychogenic factors), it is not the direct result of those conditions or influences" (Nicolosi, et al., 1989; 152).

Learning disabilities include reference to those children who do not achieve normal scores academically or on standardised tests in general and those with more specific difficulties in reading, writing and verbal responsiveness (DSM-IV, 1994; Welsh, et al., 1996). Defining "failure to learn in school" as a disability is influenced by the specific professional's outlook and preconceptions. Some professionals will exclude children with emotional disturbances or socio-economical disadvantages while others will accept these factors as contributing to learning disabilities. Others define learning disabilities purely on their educational achievements. Deficits in any of the three major domains of intellect (verbal skill, perceptual organisation and freedom of distractibility) will result in failure to learn scholastic skills (Kinsbourne, 1983).

A relevant term which is often associated with learning disability is *dyslexia,* which is seen as a specific disability in learning to read and spell in spite of adequate educational resources, normal intellect, no obvious sensory deficits and adequate socio-cultural opportunity (Cacace and McFarland, 1998; Schulte-Körne, Deimel, Bartling and Remschmidt, 1998). Nicolosi, et.al. (1989) define dyslexia as a less severe form of alexia, which is an inability to read, possibly as a result of a neurological impairment. Dyslexia appears to be a disorder of information processing that is not restricted to one sensory modality (Felmingham and Jakobson, 1995; Cacace and McFarland, 1998).

The logical and extensive definition proposed by the position statement on learning disorders of ASHA in Owens, 1984: 331 will be used in this study: " Learning disability is a general term that refers to a diverse group of developmental and educational disorders. These disorders are realised as significant difficulties in the acquisition and development of listening, speaking, reading, writing, and mathematical abilities."

1.3.4 Sensory Integration

Sensory integration as used in this study refers to the use of the term by occupational therapists which views sensory integration as the *organisation of sensation for use*, a primary function of the central nervous system. Sensory integration is information processing (Ayres, 1983; Fisher and Murray, 1991). Through integration a "whole" is revised or produced from fragmented parts (Ayers, 1983).

The term sensory integration refers to both a neurological process and a theory of the relationship between the neurological process and behaviour (brain-behaviour relationships) (Fisher and Murray, 1991; Parham and Mailloux, 1996). Normal children take in sensory information from the environment and from movement of their bodies, process and integrate these sensory inputs within the central nervous system and use this information to plan and organise behaviour, particularly the tangible, three-dimensional, gravity-bound world (Ayers, 1983; Fisher and Murray, 1991).

Children with sensory integration dysfunction form a subgroup within the larger group of children with learning disabilities. Members of this subgroup display deficits in interpreting or discriminating sensory inputs from the body and environment, without

apparent cause (for example, emotional problems, mental retardation, peripheral sensory loss and neurological damage or abnormalities)(Fisher and Murray, 1991).
In this study, the view of the occupational therapist as described by Ayres (1983) will be followed. When referring to sensory integration the occupational therapist's terminology of sensory abilities (visual and somato-sensory) will be applicable (Ayres, 1983; Fisher and Murray, 1991).

1.3.5 The holistic approach

The term *holistic approach* as used in this study can refer to Jordaan and Jordaan's (1994) view which states that the humanistic trend in psychology maintains that human beings should be studied holistically. The total configuration formed by the constituent elements should be studied in order to understand and describe the whole person in his or her world. From this philosophy develops the meta-approach which is a way of thinking about people and their existence in an intra- and inter-disciplinary manner.

According to Capra, in Nelson (1993) the world is an interconnected world, in which biological, psychological, social and environmental phenomena are all integrated and inter-dependent. Because children with auditory processing disorders, language disorders, learning disorders and sensory integration dysfunction can be disabled depending on context, ecological implications are important and a holistic approach should be considered.

1.4 DIVISION OF CHAPTERS

In Chapter 1, the problem statement and rationale of the study are presented. In the subsequent explanation of the terminology and definitions and the discussion of the theoretical background in the next chapter, the general approach of the researcher can be seen. The manner in which this problem will be approached in an attempt to find a possible solution, will be explained in the following chapters. In conclusion a critical evaluation of the study will be advanced and, in the light of the findings, recommendations will be made. In *Table 1.2*, the objectives of the different chapters of the study and the approach to solving the research problem are set out.

1.5 SUMMARY

The relationship between central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction is acknowledged in the relevant literature and in the clinical setting. Nevertheless, the present approach in the literature and clinical setting to the diagnosis and the management of central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction, is an isolated fragmented approach in which every professional involved functions in isolation. In spite of our knowledge of the interrelationship of the different conditions (central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction) which occur under the umbrella of developmental learning disorders, the recommended trans-disciplinary team approach to effect management of interrelated problems is not widely used in the clinical setting in South Africa. The relevant terminology and definitions as they will be used in the study provide a background for orientation of the study. The object of this study is to consolidate the

Table 1.2: Division of chapters

Chapter	Objective	Approach
Chapter 1: Introduction	• Problem statement and rationale of the study • Arguments in support of a holistic approach to children with learning disabilities • Discussion of terminology and definitions of terms that will be adopted in the study, namely central auditory processing disorder, language disorder, learning disability, sensory integration and holistic approach • Engaging the problem in the rest of the study will be stated to find possible solutions	• Discussion of theoretical and clinical settings concerning diagnosis and management of children with auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction. • Outline of relevant definitions and terminology • Presentation of chapters by means of a table
Chapter 2: Overview and discussion of he literature of relevant neuro-physiology and the development of modalities related to learning	• Exposition of the neuro-physiology of the sensory modalities concerned with learning • Discussion of the neuro-pathology concerning developmental learning disorders • Outline of normal development of the auditory, visual and somato-sensory systems • Outline of normal development of the motor functions involved with the sensory systems and learning • Outline of normal language development • Discussion of the inter-relationship between sensory systems, namely, multi-modal perception and the development of perceptual integration • Discussion of the implications of the foregoing theoretical findings in approaching children with a developmental learning disorder to support the holistic team approach	• Brief outlay of the anatomy and physiology of the central nervous system as an interrelated system, functioning as unit, processing all the incoming stimuli to learn and function • Brief discussion of approaches to and theories of development and learning processes of the normal child • Discussion of views and trends in literature concerning the inter-relationship between sensory systems to support the concept of multi-modal perception • Discussion of implications concerning assessment and intervention approaches using literature supporting a holistic approach as background
Chapter 3: Research methodology	• Description of the research aims, namely, to view conventional evaluation results in a holistic manner to obtain patterns that exist in the total picture of developmental learning disorders supported by the literature. A proposed model for assessment and intervention • An overview of the subjects used in the study • Discussion of the course of the study, namely, the pilot study, the main study and the analysis of the data • Analysis of the collected data using conventional statistical methods and a phylogenetic analysis strategy	• Discussion of the research design to satisfy the research aims • Selection of appropriate criteria to select appropriate subjects • Description of the procedures for collection and analysis of data by means of a pilot and main study • The use of frequency incidence correlation techniques and phylogenetic analysis techniques to prove the hypothesis that existing evaluation results of different sensory modalities and abilities interwoven in functioning can be used to determine patterns of problem groups

Table 1.2: Division of chapters (continued)

Chapter	Objective	Approach
Chapter 4: Results and discussion of the results	• Discussion of the results obtained by frequency incidence correlation statistics and phylogenetic analysis • Relating the results to the literature concerning neuro-physiology and development concerning the interrelationship between sensory and motor systems • Interpretation of the problem group patterns • Proposal of a model to obtain a synthesis to endorse the aim of the study	• Establish patterns existing in the conventional statistical analysis of the results by using tables and figures to explain the groupings of problem areas • Discussion of the relationships found by means of the phylogenetic inheritance trees • Endorse and explain the interrelationship between the phenomena and patterns found in the phylogenetic analysis results by means of information in the literature as outlined in Chapter 2 • Development of a model to deal with the interrelationship between the phenomena that have been researched; to propose a holistic team approach in evaluation and intervention
Chapter 5: Conclusions, evaluation and clinical implications of the study	• Provide a summary of the study • Evaluation of the validity, reliability and value of the study • Discussion of clinical implications • Suggestions for further research	• Summary of the study: of were the main and sub-aims of the study satisfied • Critical evaluation of the methodology of the study and the resultant findings • Discussion of the value of a holistic approach • Clinical value of the study in diagnosis and intervention strategies in a South African situation: proposal of a model for assessment and intervention

acknowledged relationship between central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction and to develop a model of a trans-disciplinary team approach for the diagnosis of and intervention into the cases of children with developmental learning disorders.

To achieve this goal a theoretical and experimental study will be carried out as presented in the following chapters. The results obtained in the experimental study will be critically evaluated to determine the effectiveness and value of the study.

CHAPTER 2: OVERVIEW AND DISCUSSION OF THE LITERATURE OF RELEVANT NEURO-PHYSIOLOGY AND THE DEVELOPMENT OF MODALITIES RELATED TO LEARNING

2.1 INTRODUCTION

To survive in a dynamic multi-modal environment, it is necessary for a human being to remain in constant communication with the environment, by receiving sensory information which must then be differentiated and integrated to form a meaningful whole (Jordaan and Jordaan, 1994). When studying this process it is necessary to have knowledge of the underlying neuro-physiological systems performing this holistic function. The neuro-physiology of the anatomical pathways concerned with learning is presented in this chapter which is followed by a discussion of the development of auditory-, visual- and somato-sensory systems in children as well as motor and language development. Thereafter, the literature pertaining to development of multi-modal perception is discussed. It is important to consider this knowledge in relation to its implications for assessment of and intervention in children who have a developmental learning disorder. Against this background, the importance of an integrated team approach is highlighted and the need for research to develop a holistic approach is indicated.

2.2 NEURO-PHYSIOLOGY OF THE MODALITIES CONCERNING LEARNING AND ASSOCIATED NEURO-PATHOLOGY

The aim of this discussion is to show how recent knowledge of the neuro-physiology of the central nervous system supports the holistic approach. The neuro-physiological knowledge important for understanding learning, with emphasise on the auditory system as an example, is outlined in order to provide background to motivate the rationale of the study. To aid understanding of the nervous system, the nervous system is classified into different sub-systems based on structure and function, but it is important to bear in mind that this classification is done only for convenience to aid the understanding of this complicated system. *No sub-system functions independently*. These functional sub-divisions interact with one another in perception, motivation and behaviour through a thicket of interconnections among neurones in the nervous system (Jordaan and Jordaan, 1994). *Figure 2.1* depicts a detailed sub-division of the central nervous system and can serve as a summary of the central nervous system, which will be used as an outline of the following discussion where appropriate.

2.2.1 Neuro-physiology of the sensory systems with emphasis on the auditory system

"Hearing is not a unitary sensory-perceptual skill" (ASHA, 1996: 43). Therefore, it is necessary to know that the central auditory nervous system is a complex system with multiple components and levels of parallel and sequential functions and that it is also an interactive organisation. Anatomically it includes nuclei and pathways in the brainstem, sub-cortex, primary and association areas of the cortex, and corpus collosum (ASHA, 1996). Information from the environment is received by the receptors and is then

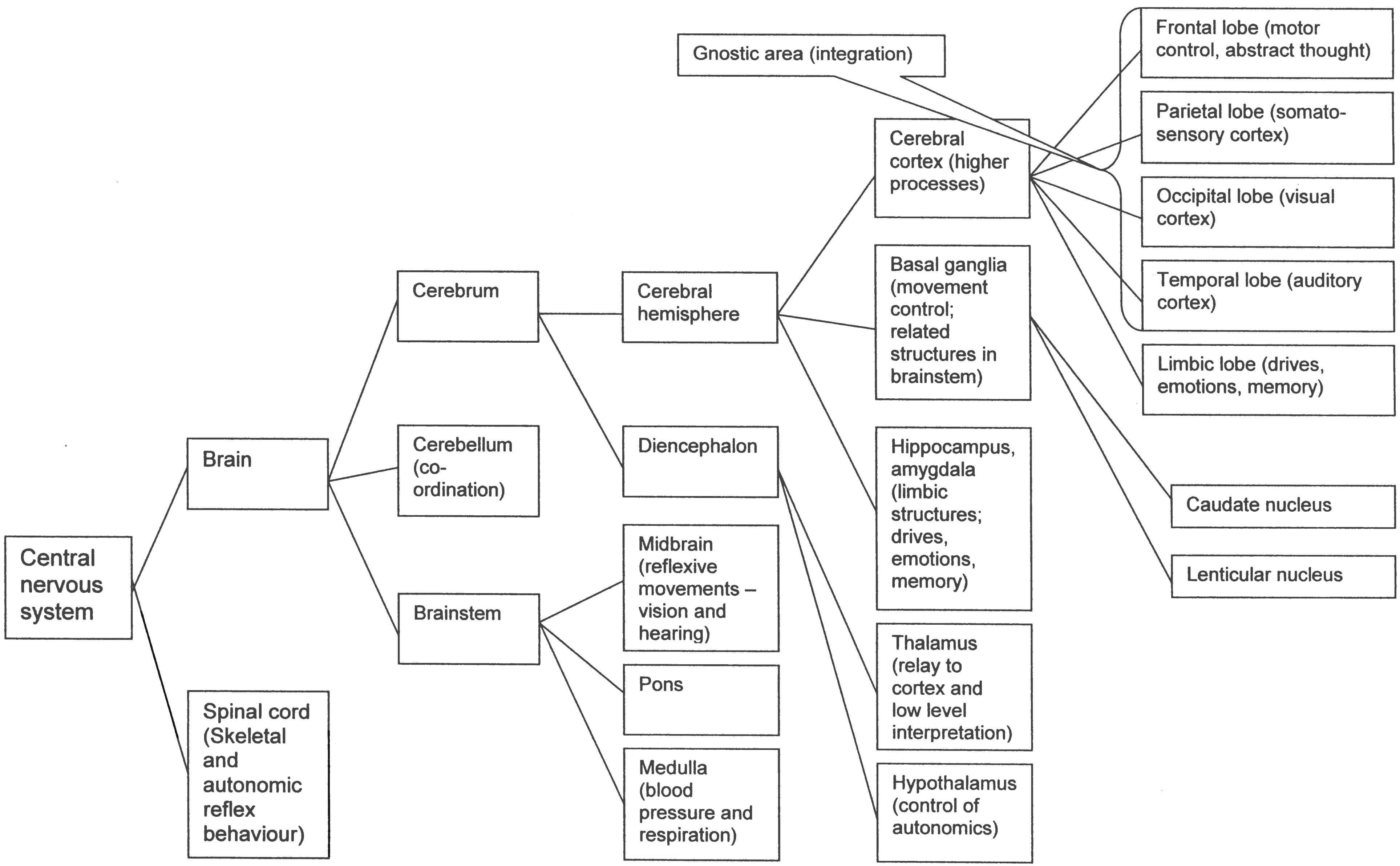


Figure 2.1. Overview of the subdivisions of the central nervous system (Adapted from; Jordaan and Jordaan, 1994; Nolte, 1999).

conducted to the sub-cortical structures through to the cortical brain where it is processed and stored.

2.2.1.1 Sub-cortical systems

The following is a brief description of the sub-cortical system and which attempts to create an objective base for the subsequent discussion. *Figure 2.2* illustrates the sub-cortical structures and their functions, involved with the conveying, perception and processing of the auditory stimuli from the cochlea through numerous structures and pathways through the brainstem and cerebrum to the cerebral cortex.

The optic nerves project directly to the diencephalon. It is significant, on the other hand, that the auditory nerves pass through the brainstem. As depicted in *Figure 2.2* a number of integrative functions are organised at the level of the brainstem, for example motor patterns and levels of consciousness, and this is accomplished by the reticular formation (Nolte, 1999).

The sub-cortical system needs to make distinctions between the attributes of sounds (intensity, spectrum, temporal dispersion) and attributes of sound sources (direction, distance, direction and speed of movement, nature of the source)(Masterton, 1992). Understanding spoken language ultimately depends on the initial sensory detection and perceptual analysis of the acoustic input to the central auditory nervous system. Nevertheless, it is important to be aware of the nature of the interaction of the sensory/perceptual system information with the central, higher-level information resources (ASHA, 1996).

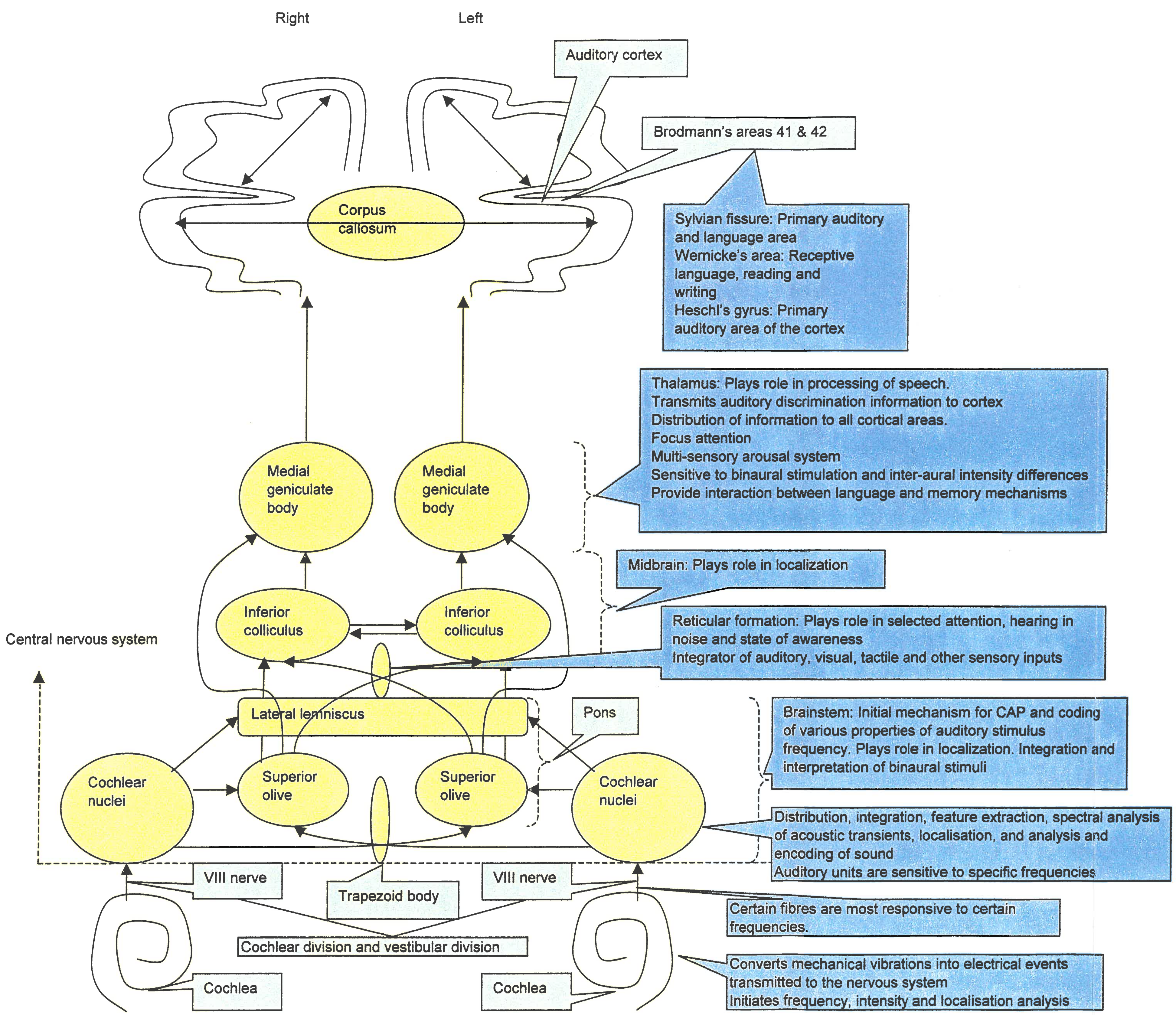


Figure 2.2: The ascending auditory pathways (Figure structured from information from; Northern and Downs, 1991; Jordaan and Jordaan, 1994; Zimmerman, 1994; Nolte, 1999.Other sources; Noback, 1985; Akmaijan, et.al., 1992; Masterton, 1992; Owens, 1992; Musiek and Lamb, 1992; Bellis, 1996; Fitch, Miller and Tallal, 1997).

A model of brain function must thus take into account the effects of the sub-cortical structures on the cortex and vice-versa. The intricate functioning of the brain in everyday life is complex because at all times attention is on complex stimuli from a variety of sources. Although engaged in one specific task, the central nervous systems are responding to many inputs, so that a single a task requires many different types of thinking and processing (Murray, 1991).

2.2.1.2 Cortical areas

"The cerebral cortex is a sheet of neurons and their interconnections" (Nolte, 1999: 507). The function of the cortex is the basic aspects of perception, movement, and adaptive response to the outside world, as well as the higher functions of language and abstract thinking (Nolte, 1999).

Before new brain imaging techniques like positron emission tomography and functional magnetic resonance imaging came into use, knowledge of higher mental functions was based largely on clinical case studies. The progress of computer technology and the development of the above-mentioned methods and event-related electro-encephalography and magneto-encephalography brought about dramatic advances of knowledge of the higher cortical functions (the working brain)(Akmajian, Demers, Farmer, and Harnish, 1992; Lauter, 1992; Fitch, Miller and Tallal, 1997; Friederici, 1997; Nolte, 1999).

Controversy exists, however, among researchers (in Nolte, 1999) about the exact localisation of function in the cerebral cortex. Nevertheless, many years of clinical experience show that reasonably predictable deficits are found after damage at various cerebral sites. This could mean that a given function is located in a particular area or that the area performs one crucial step in the function, or that the area facilitates the activity of one or more other structures (Nolte, 1999).

Simply stated, the cortex of each cerebral hemisphere is traditionally considered as made up of primary sensory areas, the primary motor area, association areas, and limbic areas. Many of these areas are associated with one of Brodmann's anatomically defined areas (in Nolte, 1999) and the commonly used Brodmann numbers are indicated in brackets in *Figure 2.3*. As seen in *Figure 2.3*, the primary somato-sensory cortex is in the parietal lobe, the primary visual cortex is in the occipital lobe and the primary auditory cortex is in the temporal lobe. Brodmann's areas 41 and 42 on the transverse temporal gyri receive most of the auditory radiation from the medial geniculate nucleus and thus form the primary auditory cortex. Wernicke's area is the area containing the mechanisms for the formulation of language (Nolte, 1999). Linguistic analysis in Wernicke's area is assisted by the angular gyrus and the supra-marginal gyrus. The angular gyrus and the supra-marginal gyrus integrate visual, auditory and tactile information and assist linguistic representation (Owens, 1992). Area 42 which is flanked by area 22 (superior temporal gyrus) is the auditory association cortex (Northern and Downs, 1991; Nolte, 1999). The association cortex is commonly divided into two broad types (Nolte, 1999):

- uni-modal association areas: Adjacent to a primary area and devoted to an elaboration of the business of the primary area,
- multi-modal or hetero-modal association areas: concerned with high-level intellectual functions.

Additionally, the inferior portion of the parietal and frontal lobes are also sensitive to acoustic stimuli. The insula also have a large number of fibres sensitive to acoustic stimuli (Bellis, 1996).

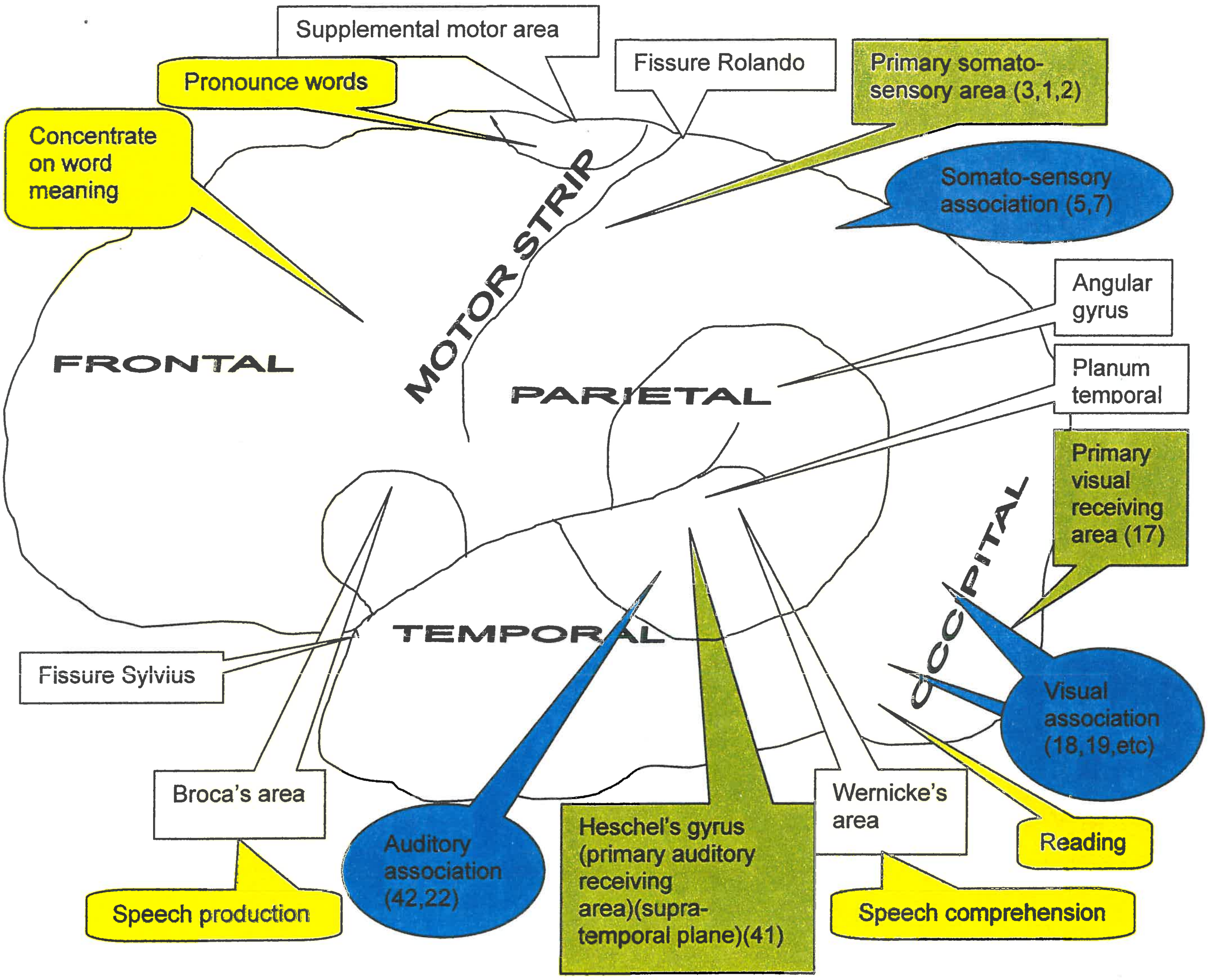


Figure 2.3: Landmarks associated with the modalities of learning of the left cerebral hemisphere. (Derived from: Akmajian, et al., 1992; Jordaan and Jordaan. 1994; Bellis, 1996; Nolte, 1999). Key: White text boxes indicate anatomical features and areas, green text boxes indicate primary sensory areas, blue texts boxes indicate association areas and yellow text boxes indicate functions.

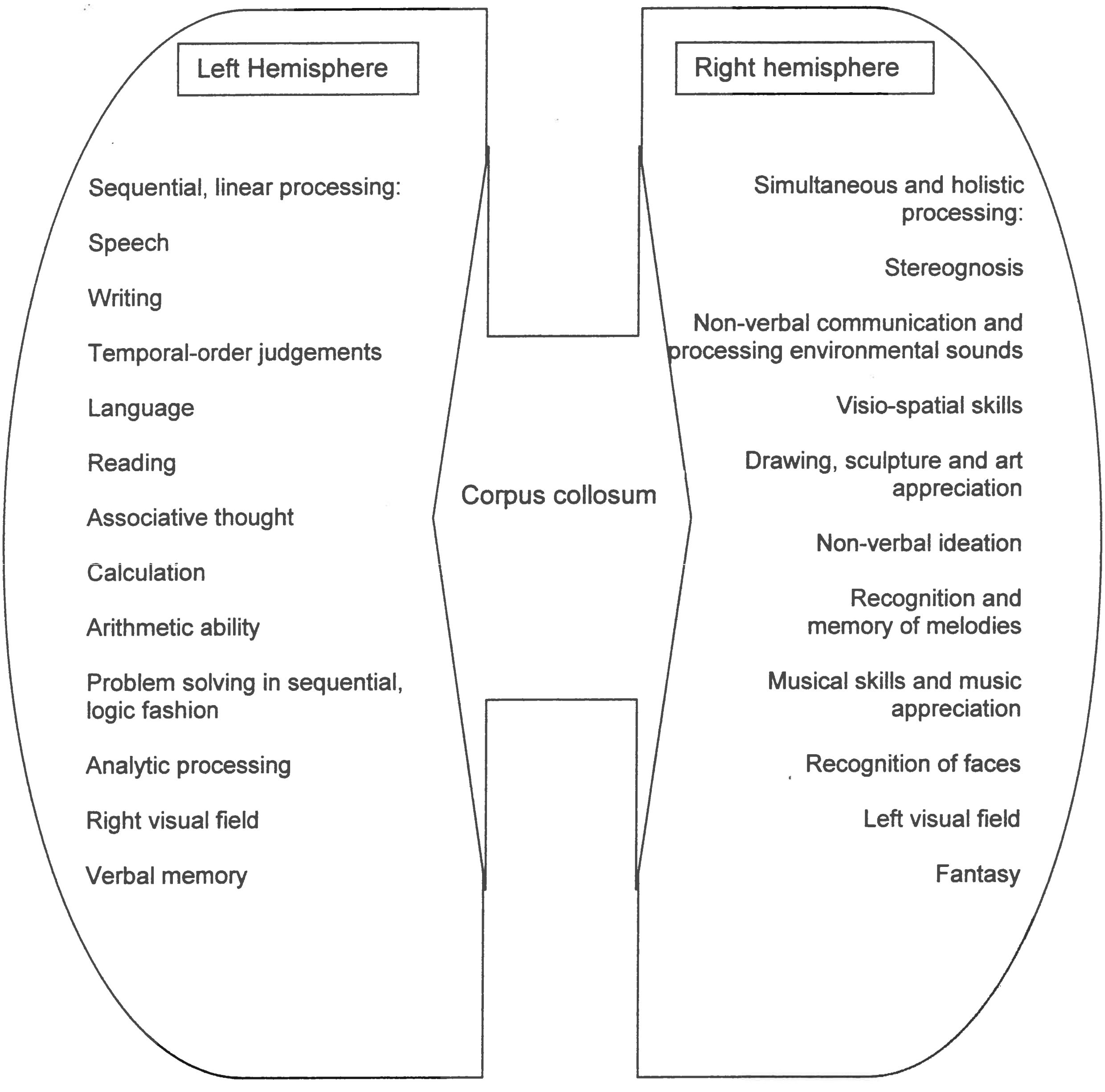
Figure 2.3 serves as a summary and reference in the following discussion of the cortex

The details of the ways in which different areas of the cortex and other parts of the central nervous system co-operate to perform a simple perceptual task are still unknown (Nolte, 1999). There is also a difference between the functioning of the two cortical hemispheres which adds another dimension.

2.2.1.2.1 Hemispheric specialisation

The right and left cerebral hemispheres are specialised for different functions. Language tends to be lateralised in the human brain, and the hemisphere which is more important for comprehension and production of language is commonly called the dominant hemisphere. This correlates with the planum temporale (including Wernicke's area) being larger on the left than on the right (Fisher, Murray and Bundy, 1991; Murray, 1991; Owens, 1992; Bukatko and Daehler, 1995; Gordon and Ward, 1995; Bellis, 1996; Nolte, 1999). Likewise relatively larger areas are found in the right frontal lobe and the left occipital lobe (Murray, 1991). These asymmetries are present before birth, indicating a left-hemisphere dominance for language to be genetically determined (Murray, 1991; Gordon and Ward, 1995; Nolte, 1999). It is, however, more accurate to refer to the hemispheres as complementarily specialised. The degree of hemispheric specialisation also varies among individuals (Akmajian, et al., 1992; Owens, 1992).

The most important difference between the left and the right hemispheres is the style or approach that each is thought to use in processing information. The left hemisphere is hypothesised to process information in a sequential, linear manner. It is thus superior at observing and analysing details. The right hemisphere has been described as superior at simultaneous processing and holistic thinking (Fisher, et al.,1991; Murray, 1991). *Figure 2.4* gives a schematic summary of the functions thought to be processed in each of the hemispheres.



<u>Figure 2.4</u>: Complementary specialisation of cerebral hemispheres (Developed from: Akmajian, et al., 1992; Owens, 1992; Jordaan and Jordaan, 1994; Nolte, 1999)

Care should be taken not to oversimplify the differences in function of the two hemispheres. Other aspects of the functional organisation of the brain must also be taken into consideration. Cortical functions also differ between anterior (frontal lobes have an executive function) and posterior (play a major role in reception, association, and integration of sensory Inputs and motor outputs) regions (Murray, 1991).

2.2.1.2.2 The left hemisphere

It is hypothesised that to develop the specialisation of language processing, the left hemisphere, which is the primary language centre of the brain, reduced some of its connections with the limbic system and developed more connections between the various other sensory association areas (Bear, 1983). An example is the arcuate fasciculus that connects Wernicke's area and Broca's area, which has a more dominating function in the left hemisphere (Jordaan and Jordaan, 1989). Because of the diminished communication of the left cortex with the limbic system, the left cortex has a more analytical function (Bear, 1983; Akmajian, et al., 1992). The cognitive functions of the left cortex include the direct associations between the different sensory modalities. Concerning the auditory paths in the left cortex, the left cortex is primarily responsible for association of language concepts and integrated association of the other sensory modalities (Jordaan and Jordaan, 1989; Gabbard, 1992). The remaining connections with the limbic system, especially the amygdala, are associated with the learning process of sequential associations and memory involved with language abilities (Bear, 1983).

Right ear dominance indicates left hemisphere dominance for speech. Although there are some ipsi-lateral inputs to each cortex, they are thought to be suppressed. This advantage was originally thought to exist only for linguistically meaningful stimuli, but the same advantage has been found for nonsense syllables, speech played backward, consonant-vowel syllables, and even small units of speech such as fricatives. The left hemisphere may be dominant for more than the phonetic structure of language. It is also dominant for a number of non-linguistic functions, for example, temporal order functions, complex motor sequencing (speech being one of these sequences) and associated thought. (Akmajian, et al., 1992; Owens, 1992; Jordaan and Jordaan, 1994; Bukatko and Daehler, 1995; Nolte, 1999).

Autonomy of the particular neural system responsible for structural aspects of language develops over time. Once matured, the system can be localised in the left hemisphere (possibly Broca's area). This system however constitutes one of several subsystems in a network representing speech and language. Speech and language processing is an interaction between widespread subsystems (both cortical and sub-cortical levels). Interconnectivity at cell level is compatible with this claim (Frederici, 1996). Further studies support the existence a cortical network supporting language processing in Broca's and Wernicke's areas (Gollegly and Musiek, 1993; Fitch, et al., 1997; Frederici, Hahne, and Von Cramon, 1998). For example, production of language starts in Wernicke's area where the message is organised and then transmitted through the arcuate fasciculus to Broca's area in the frontal lobe (Owens, 1992; Bellis, 1996; Fitch, et al., 1997). Broca's area contains motor programs for the generation and co-ordination of language (Owens, 1992; Nolte, 1999). However the mechanisms through which the human brain perceives and processes speech are not yet well understood (Fitch, et al.,1997).

Studies (Price, Wise, Warburton, Moore, Howard, Patterson, Frackowiak, and Friston, 1996; Fitch, et al., 1997) using positron emission tomography showed that cortical activities are not isolated. Activation in Wernicke's area was observed in response to hearing and repeating words, as well as when phonological judgements on heard syllables or non-words were made. A region of the left posterior temporal lobe also responded when subjects listened to words. Extra-sylvian regions in the left ventral temporal and posterior, inferior parietal lobes are active when subjects retrieve words from semantic memory. Activation of Broca's area during auditory word processing has been observed during phonological judgements on heard stimuli, the retrieval of words, semantic judgements on heard words and silent repetition of non-words, thus auditory-verbal short-term memory tasks. Thus, for example, while hearing a word different parts of the brain become active with activities observed in the posterior temporal lobe with peaks of activation in the middle temporal gyrus, inferior temporal sulcus and inferior temporal gyrus as well as in the left inferior frontal gyrus (Akmajian, et al., 1992; Price, et al., 1996). What is therefore under discussion here, is a multi-modal area, namely, the parieto-occipital-temporal overlap area being active. The person immediately puts the word heard into the context of associated words and meanings, thus integrating visual, auditory, somato-sensory and emotional memories (Moore, 1994-1995).

The contributions of the two hemispheres to academic performance, however, are not well documented, perhaps because of the complexity of academic tasks. There are however indications that both hemispheres contribute to the learning of reading, but with more significance of the left hemisphere (Murray, 1991).

2.2.1.2.3 The right hemisphere

Because the right cortex developed most of its connections with the limbic system its functions are concerned with holistic processing. Concerning audition, it is primarily involved with the perception of non-temporal information like tonal texture, musical relations and harmonics (Bear, 1983). The right hemisphere thus also processes auditory stimuli holistically (Akmajian, et al., 1992).

The right dorsal and lateral prefrontal cortex receives massive inputs from somato-sensory, visual and auditory association areas. The dorsal and lateral prefrontal cortex also play a critical role in working memory. The pre-frontal area is thus also involved with planning, solving problems and maintaining attention (Nolte, 1999).

There is evidence that the right hemisphere plays a special role in producing and comprehending the affective aspects of the prosody of speech and language. The right inferior frontal gyrus is involved in producing prosody and the right posterior temporo-parietal region in comprehending it (Gabbard, 1992; Nolte, 1999). Experiments done with "split-brain" patients indicate clearly that the right hemisphere has some capacity for the comprehension of language and the organisation of non-verbal responses (Nolte, 1999).

Although progress continues to be made in respect of understanding how language is stored and processed by the brain, it is still far from clear which neuro-anatomical structures are essential for the encoding and decoding of linguistic stimuli. Nevertheless, researchers agree that speech results from an integrated cortical and sub-cortical system. Researchers therefore share an awareness that the neural sensory, motor and associative mechanisms are interconnected and this concept of integration is basic to understanding how the brain functions to encode and decode language (Akmajian, et. al. 1992; Fitch, et al., 1997).

2.2.1.3 Neural communication network

The hemispheres are dependent on connecting fibres for learning skills. Once learned the skills for which the left hemisphere is specialised become more localised and become less dependent on multiple inputs. The left hemisphere is less dependent than the right hemisphere on these connections for skill maintenance (Murray, 1991).

There are three basic types of nerve fibre tracts that form the neural communication network, namely:

- association nerve fibres connect different portions of the same hemisphere (for example the posterior and anterior regions),
- projection fibres connect the cortex with lower portions of the brain and spinal cord,
- transverse fibres (corpus collosum) interconnect the cerebral hemispheres, also referred to as commissural fibres (Noback, 1985; Murray, 1991; Owens, 1992; Nolte, 1999)

Important for speech and language is the massive transverse fibre called the corpus collosum (Murray, 1991; Akmajian, et al., 1992). The corpus callosum ordinarily connects and organises the activities of the two hemispheres together into a unitary consciousness (Katz and Cohen, 1985; Nolte, 1999).

The corpus callosum is by far the largest fibre bundle in the human brain. Most afferents to the cortex of the contra-lateral hemisphere pass through the corpus callosum. Of these fibres most interconnect roughly mirror-image sites, but a substantial number end in areas different from those in which they arise. Although parts of the somato-sensory and visual cortices receive no commissural fibres, all areas of the parietal and occipital association cortices do, so each hemisphere has access to data from the contra-lateral half of the body and from the outside world (Bellis, 1996; Nolte, 1999).

Efferent auditory pathways run from the auditory cortex to the cochlea parallel with the afferent system. The various efferent pathways are however not well known. It is believed that the efferent auditory system plays a role in detecting an auditory signal in noise and has inhibitory effects concerning the cochlear hair cells and the auditory reflex (Noback, 1985; Bellis, 1996).

In conclusion to this section on the neuro-physiology of the sensory modalities it can be said that the number of properties ascribed to the brain is large, as is the number of brain regions mediating those processes. The mapping of representations in the brain relies on multiple serial, parallel, and distributed neural networks. Within well-defined limits, the individuality of the brain organisation and the pathologies that can affect the brain are manifest in different ways (ASHA, 1996).

2.2.2 Neuro-pathology related to central auditory processing-, language- and learning disabilities.

In the following discussion a few examples are presented to show how pathologies of the central nervous system can affect central auditory processing and subsequent processing of language and learning. Because of the complexity of the neuro-physiological system, it is impossible to describe all the pathologies and their consequences in this dissertation and therefore, only the following examples will be outlined.

Central auditory processing disorders can be observed in some patients who show clear evidence of central nervous system pathology. These brain lesions are situated cortically in the left and right temporal and parietal lobes or sub-cortically in thalamus, basal ganglia, and brain stem structures. The various aspects of hearing (laterality, location, pitch, and timing) mediated by different neurones and neural coding mechanisms, especially on sub-cortical level, can each be differentially susceptible to pathologies. (ASHA, 1996). One consequence of damage to the auditory pathway rostral to the cochlear nuclei is that it does not cause deafness in either ear, but causes problems with localisation of sounds and may cause difficulties in separating sounds from background noise (Nolte, 1999).

Lesions of the corpus collosum will result in deficits related to inter-hemispheric communication (Bellis, 1996). Recent research suggests that deficits in hemispheric integration may also be an important factor in learning disabilities (Moore, Brown, Markee, Theberge and Zvi, 1996). Cortical lesions can disrupt a variety of central auditory processes and typically can involve both ears. For example, judgement of temporal order can be bilaterally impaired following a lesion or neuro-pathology in the left and/or right temporal lobes. Lesions of the right temporal-parietal area may result in bilateral difficulty with spectral analysis and contra-lateral deficits on dichotic listening. Monaural low redundancy speech tasks have been reported following cortical lesions (ASHA, 1996).

On the cortical level the effect of lesions are however not so isolated. As stated in section 2.2.1.2.2, cortical functions, for example, listening to a word, are not localised in one specific region of the brain. For instance it is found that destruction of Broca's area deprives the motor cortex of the instructions needed to generate language, but the muscles involved would be normal in other activities and comprehension of language would be relatively unaffected (Bellis, 1996; Nolte, 1999). Other researchers (in Price, et al., 1996; Fitch, et al., 1997; Friederici, 1997; Friederici, Hahne and von Cramon, 1998), however, found that lesions in Broca's area may also lead to failures in language comprehension. Likewise, with destruction of Wernicke's area, this pathology would leave Broca's area unchecked so that words could be produced without regard for their meaning (Bellis, 1996; Nolte, 1999). The articulation of speech sounds is however subtly influenced. This confirms the existence of neural projections (in the arcuate fasciculus) from Wernicke's areas to Broca's area (Friederici, 1983; Price, et al., 1996; Friederici, 1997; Friederici, et al.,1998; Nolte, 1999)

Katz (1992) developed a classification of central auditory processing disorders based on site-of-lesion tests (the staggered spondaic word test) that suggests brain lesions, dysfunction or developmental lag *of a particular brain region*. The four categories suggested by Katz (1992) are the decoding-, tolerance-fading memory-, integration- (two types) and organisation categories. Bellis (1996) also derived categories from results of central auditory tests, namely, auditory decoding-, integration-, associative- and output-organisation deficits. *Table 2.1* is a classification of central auditory processing disorders in relation to the affected anatomical structures and the related problems derived from the classification model of Katz (1992) and the classification of central auditory processing disorders by Bellis (1996).

Table 2.1: Classification of central auditory processing disorders developed by Katz (1992) and Bellis (1996).

Category	**Involved region of the brain**	**Associated problems**
Phonemic decoding (Auditory Decoding)	Posterior temporal region (Wernicke's area) (Primary auditory cortex)	• Poor decoding skills. • Poor sound recognition and blending. Poor auditory closure skills. • Reading, spelling, receptive language and articulation problems.
Tolerance-fading Memory	Anterior temporal region and frontal lobes	• Poor auditory memory, figure-ground and motor programming skills. • Poor reading comprehension, expressive language. • Handwriting, attention deficit, fearful.
Integration	Type 1: Corpus callosum and/or parietal-occipital region	• Difficulty in multi-modal tasks. • Poor phonemic knowledge and auditory-visual integration. • Severe reading and spelling disability (dyslexic) and extremely poor handwriting. • Difficulty in use of symbolic language and prosody. • Poor music skills.
	Type 2: Anterior region of the brain and anterior portion of the corpus callosum	• Poor motor planing. • Less difficulty in school subjects and may not have auditory-visual integration problems.
Organisation (Organisation-Output)	Anterior temporal region and posterior frontal lobe and efferent system	• Poor recall and sequencing skills. • Disorganised. • Reversals in spelling and reading and poor handwriting. • Motor skills often affected.
Association	Primary associative cortical regions communication	• Poor receptive language. • Poor pragmatic skills.

This classification of Katz (1992) and Bellis (1996) can be applied to both adults and children. However, children with central auditory processing disorders with pathology of the central nervous system are in the minority. A larger percentage of children with central auditory processing disorders presents with maturational delay and/or morphological abnormalities of the central nervous system (Musiek, Gollegly and Baran 1984; Musiek, Gollegly and Ross, 1985; Musiek, et al., 1990; Musiek and Chermak, 1994; Musiek and Chermak, 1995; De Conde-Johnson, et al., 1997; Chermak, 1998). It can thus be suggested that the group of children with maturational delay can not successfully be accommodated in the classification as described in *Table 2.1*.

Concerning learning disabilities, Ayres (1983) has attributed the contributions of sub-cortical structures to normal development and noted possible indicators of sub-cortical dysfunction in some children with learning disabilities. However, learning disabilities are considered by most psychologists and educators to be reflective of dysfunction primarily of higher cortical processes. Although sensory integrative dysfunction may exist along with cortical dysfunction, the actual problems learning disabled children experience probably result from problems in cortical function. Nevertheless, Kraus, McGee, Carrell, Zecker, Nicol and Koch (1996) found that some children with learning disabilities have deficits in the auditory pathway even before conscious perception. They thus acknowledge both cortically involved and sub-cortically involved subgroups of children. Likewise, research on hemisphere dysfunction (in Murray, 1991) has described two types of children with learning disabilities, namely:

- children with left hemisphere dysfunction, which is strongly associated with language deficits and reading disability. They also show problems in decoding, in complex mathematical calculations and in sequencing tasks such as handwriting,

- Children with right hemisphere dysfunction, which shows a non-verbal learning disability, with problems in organisation and synthesising of information, mathematical concepts, pragmatics of language, attention, visual-spatial skills, handwriting and they appear to be clumsy.

Research findings based on measures of perceptual asymmetry, as well as morphological and physiological studies, are inconsistent, but they do suggest that some children with learning disabilities show patterns of cerebral organisation that differ from those of most normal children. The reason for the inconsistency in results may be due to variability in definitions and the fact that children with learning disabilities are not a heterogeneous group (Murray, 1991; Hugdahl, Heiervang, Nordby, Smievoll, Stevenson, and Lund, 1998).

In the same context, clinical observations suggest that dyslexia results primarily from lesions in the auditory cortex, both primary and association cortices. However, other areas, namely, the frontal cortex, the thalamic nuclei, the lateral-geniculate nucleus of the visual system and the medial-geniculate of the auditory system may also be damaged. Although the neuro-anatomical data is inconclusive, it can be postulated that dyslexia has a complex neurological basis involving multiple sensory and association areas of the brain. Researchers also found anatomical atypical features in people with dyslexia, involving the parietal and temporal region, the Sylvian fissure, Heschl's gyrus and the corpus collosum (Katz and Cohen, 1985; Chase, 1996; Moore, et al., 1996; Fitch, et al., 1997; Cacace and McFarland, 1998; Hugdahl, et al., 1998; Chermak, et al., 1999). These atypical anatomical features, also found in families with dyslexic individuals, suggest foetal neuro-developmental pathology which can be seen in magnetic resonance imaging studies showing abnormal asymmetries in the entire temporal lobe as well as in the prefrontal region of the cortex (Chase, 1996; Fitch, et al., 1997; Cacace and McFarland, 1998).

These structural anomalies as seen in dyslexic individuals (in the auditory areas of the cortex) however, also suggest functional anomalies. The accumulating neuro-morphologic evidence thus suggests auditory dysfunction in learning disability, dyslexia, attention deficit disorder and central auditory processing disorder (Chermak, et al., 1999). Studies using positron emission tomography and functional magnetic resonance imaging techniques also found atypical activation of brain areas of people with dyslexia when reading, during visual and during memory tasks. These studies suggest weak connectivity between brain areas and a deficit in visual-motion processing (Cacace and McFarland, 1998; Hugdahl, et al., 1998).

Important to these suggestions are the advances made in understanding the working brain. Also of importance are discoveries of remarkable brain plasticity in learning and development and how this is accomplished. Plasticity refers to the observation that the organisation of the central auditory system can be modified or reorganised by cochlear pathology, central lesion, maturation, experience, learning or rehabilitation (Bukatko and Daehler, 1995; ASHA, 1996; Bellis, 1996). It can thus be said that plasticity of the central nervous system contributes to additional modification of neural representations of auditory stimuli. The representation of a given stimulus parameter is probably modified at every successive level of the auditory neural pathway (ASHA, 1996). An example of cross-modal plasticity can be seen in the activation of the upper regions of the temporal lobe of the cortex (auditory area) by sign language in congenitally deaf people (Niroshimura, Hashikawa, Doi, Iwaki, Watanabe, Kusuoka, Niroshimura and Kubo, 1999). In addition, there is an increasing understanding of the holistic properties of brain function such as inter-sensory integration. All this adds to the concept that what goes on in the nervous system must reflect in behaviour and vice versa (Lockman and Thelen, 1993).

It can be said that, with all the available knowledge, little evidence is found to support the idea of specialised brain activity in humans for processing speech and linguistic information as opposed to other acoustic complex information (Breedin, Martin, and Jerger, 1989; Fitch, et al., 1997). New knowledge suggests that neural representation of acoustic linguistic processing occurs over a more widely distributed neural system than was once believed. This processing process begins in the auditory nerve (temporal and frequency information) and follows a complex path with continual processing to the cortex where higher-order processing of speech signals ultimately occur (semantics and syntax).

2.3 HUMAN DEVELOPMENT: DEVELOPMENT OF THE MODALITIES RELATED TO LEARNING

The human brain is the most complicated structure in the body and its development processes are equally complex (Chase, 1996). The study of the human development of different sensory modalities is complex and extended. It is beyond the scope of this study to go into these issues in depth. A brief illustration of the inter-relationship of the sensory modalities and motor development is however necessary as background to support the research question.

A number of theoretical views of developmental psychology have emerged from the years of study of human development. *Table 2.2* outlines the different views and their

Table 2.2: Theoretical views of developmental psychology

Approach	Basic components of developmental theory	Examples of researchers
Biological-maturation	• Development is the result of inherited factors. • Requires no stimulation from the external environment • Nativist theory • Developed developmental schedules (norms) (milestones).	Gesell, Shirley and McGraw (1946)*
Psychosocial	• Individuals' lives are shaped by the way in which they cope with their social experiences • Ego adaptation – humanistic - school of thought • Personality development progresses through stages • Adaptive modes of functioning to meet demands of the society for identity	Erikson (1963)*, Maslow *
Learning-behavioural (behavioural analysis)	• Primary motivator of development and behaviour is the environment • Operant conditioning and classical reward and punishment • Observational learning • Social learning (environment and cognition key factors) • Empiricist's view • Development is continuous and cumulative	Watson (1928)*, Skinner (1957, 1974)*, Kohlberg, Bandura (1977, 1986, 1989)* and Mischel (1984)*
Cognitive-developmental	• Individual discovers solutions primarily through interaction with the environment (Interaction between nature and nurture) • Developmental process is the interaction of biological maturation and environment • Basic mental structure is a scheme (co-ordinated and systematic pattern of action and reasoning) • Cognitive structures develop as the result of organisation and adaptation • Child seeks equilibrium between own abilities and environment by assimilation and accommodation • Describes stages of cognitive development (sensori-motor, pre-operational, concrete and formal)	Piaget (1952, 1963)*

Table 2.2: Theoretical views of developmental psychology (continued)

Approach	Basic components of developmental theory	Examples of researchers
Information-processing	• Analyse cognitive activities in terms of successive stages of information processing (attention, perception, memory, thinking and problem solving) • Structures and processes have an inherent basis, but experience is important for effective operation • Cognitive development is quantitative (acquisition of more effective structures) • Humans have limited ability to process information	Schmidt (1988)*, Klahr (1989)* and Wallace *
Contextualist (ecological, socio-cultural, ethological)	• Emphasise the role of the larger environmental context with interaction of the biological structures • Historical period important for psychological development • Human development inseparable from cultural, historical legacy and evolutionary pressures • Ecological forces and systems at different but inter-related levels	Bronfenbrenner (1986, 1989, 1993)*, Vygotsky (1962)*, Sameroff (1987)*, Lorenz (1963, 1966)*, Tinbergen (1951)*, Hinde (1989)*, Kleinginna and Kleinginna (1988)*, Morris (1988)*
Developmental Bio-dynamics	• Interdisciplinary integration of theories and findings related to the behavioural study of perception and action • Continual and intimate interactions between the nervous system (brain) and the periphery (body)	Lockman and Thelen (1993)

(Information derived from and authors* quoted from: Clark and Allen, 1985; Gabbard, 1992; Lockman and Thelen, 1993; Bukatko and Daehler, 1995) basic theories. The pooled knowledge of the assorted approaches gives a better understanding of the development. Human development is, however, a broad subject and therefore only a framework of the development of aspects important to learning will be outlined to illustrate the integration process necessary for the development of the child as a whole.

Most developmental theories explain child development as the interplay between human biological capacity and maturation and the influence of the environment on the behavioural experiences of a child (Clark and Allen, 1985). Theories can be described with respect to the particular researcher's emphasis on and weighting of one of these aspects as being more important. Generally speaking, theorists agree that both biological maturation and environmental experiences play a role in human development.

Neuro-physiological development of the auditory system, for example, can be described as following the pre-operational period and then the period of onset of hearing and maturation. A number of embriologic processes occur during the pre-operational period, namely, induction, proliferation, migration, aggregation and differentiation of Golgi type I cells. During the maturational period additional processes are expressed, namely, differentiation of Golgi type II neurones, cell death and forming of synapses and myelinisation. These processes are important in the development of a functional auditory system (Willard, 1990). The assumption can be made that similar periods of neuronal development apply for other sensory systems as well.

Developmental patterns are more than a list of changes and accomplishments. Each child's growth has its individual pattern. Nevertheless development is predictable and follows an orderly sequence. Milestones are attained at about the same age in most children. Although much development is the result of maturation, opportunity for learning is needed in order for a child to develop (Owens, 1984, Akmajian, et al.,1992; Gabbard, 1992).

Development is thus also aided by stimulation from the environment. Early foundations are critical for the development of functioning on a higher level. Nevertheless, although there may be certain critical periods during early development when a child is particularly responsive to specific influences, the human body has resilience enabling it to overcome adverse experiences or lack thereof (plasticity)(Gabbard, 1992; Owens, 1992; Chase, 1996; Niroshimura, et al., 1999).

Perception, the interpretation of sensory information from visual, auditory, and other sensory receptors, is how the child receives information from the environment. Learning is a means of acquiring new skills and behaviours from experience by using the incoming information and is an important form of adaptation to the environment (Bukatko and Daehler, 1995).

In summary it can be said that development must be viewed as a continuous process and proceeds stage by stage in an orderly predictable sequence although individuals may differ greatly (Clark and Allen, 1985; Owens, 1992).

2.3.1 Development of the auditory system

The anatomical structures and functional ability necessary for auditory perception are present pre-natally and development of auditory functions continues through to adolescence. At birth the infant is already nine months old and the auditory system is already in an advanced stage of development (Meyer, 1993). The auditory nerve and the lower parts of the brainstem are fully myelinised at birth. Myelination of the inferior colliculus and medial geniculate is still unfinished at birth. The thalamo-cortical and cortical fibres myelinise over a few years after birth and subtle changes continue until the age of twenty years (Hugo, 1981; Willard, 1990; Meyer, 1993).

At birth the infant can discern linguistic stress, location, fundamental frequency, intensity and duration (Hugo, 1981; Kuhl, 1987; Gabbard, 1992; Owens, 1992; Meyer, 1993; Bellis, 1996). During the first year of life a refinement of responses on auditory and speech signals occurs. This maturation of auditory perception continues for a number of years and refinement of abilities continues until adolescence (Hugo, 1981; Gabbard, 1992; Meyer, 1993).

The anatomical asymmetry in the auditory association areas of the cortex in the brain that can be demonstrated as early as thirty weeks of gestation in humans, and which persists into adult life, is presumably due to higher neurone and synaptic survival in the left than in the right cerebral hemisphere in most people. This increased survival results from increased cortical activity in this hemisphere. The presence of this anatomical specialisation so early suggests that infants between four and twelve months of age can perceive sounds or phonemes representing distinct qualities of human speech, a capacity analogous to detectors of orientation in the visual system. As an infant experiences a specific language environment the ability to recognise phonemic contrasts in speech outside his native language are diminished at about the end of the first year of life (Kuhl, 1987; Meyer, 1993; Gordon and Ward, 1995).

As language function matures, linguistically dependent auditory perception and processing skills will be acquired as part of this process, so that perception and language develop side by side (Gordon and Ward, 1995).

2.3.2 Development of the visual system

The visual world is the richest source of information about the external environment for human beings (Gabbard, 1992) and it can thus be said that vision may have primacy among the senses (Butterworth, 1981). Of all the senses none is as complex as the visual system and none is as uni-dimensional (Bloch, 1994).

Visual perception is the ability to interpret and use what is seen. Interpretation is a mental process involving cognition, which gives meaning to the visual stimulus. It is the continuous combined impact of visual experience, inter-sensory communication, and cognitive growth that serves the development of visual perceptual abilities. In this frame of reference, perception is viewed as a cognitive process that changes as a function of learning, labelling and experience (Kramer and Hinojasa, 1993).

Most visual perception and processing skills are present at birth or shortly after birth and rapidly develop during infancy and early childhood towards almost the adult skill level. Refinement of the skills, however, continues until adolescence (Gabbard, 1992; Owens, 1992; Bukatko and Daehler, 1995).

A number of visual perceptual abilities, namely, spatial awareness and depth perception develop in association with kinaesthetic perception, whereas visual-motor co-ordination combines both visual and kinaesthetic perceptions to make controlled and co-ordinated bodily movements.

Of importance is that the visual system has neural interconnections with all the other sensory systems. During the processing of visual information, input received through the visual system is integrated with information from the other sensory systems (Kramer and Hinojasa, 1993).

2.3.3 Development of the somato-sensory system

The somato-sensory (body sense) system encompasses different types of sensation, namely pain, temperature, touch, proprioception (perception of position), kinaesthesia (perception of movement) and stereognosis (perception of the size and shape of objects by touch). Thus, the combination of tactile and proprioceptive inputs can be referred to as somato-sensory processing (Ayres, 1983; Royeen and Lane, 1991; Nolte, 1999).

"Touch is our first language" (Royeen and Lane, 1991:108). It is the first system to function in utero. The vestibular system is also fully developed at birth (Blanche, Botticelli and Hallway, 1995).

Both tactile and proprioceptive systems are considered to play a primary role in early development, serving as foundations for subsequent social, emotional, and cognitive development. Tactile exploration becomes associated with visual exploration early in infancy. The baby uses both forms of exploration for successful environmental interaction (Royeen and Lane, 1991).

Tactile and proprioception abilities are present at birth but refinement of these skills develops rapidly in infancy and early childhood with further refinement up to adolescence. Body and spatial awareness, however, are not present at birth and develop during infancy and early childhood (Royeen and Lane, 1991; Gabbard, 1992; Owens, 1992). Regarding body awareness, it must be borne in mind that the ability to identify body parts depends heavily on both conceptual and language abilities and other sensory perceptions. Spatial awareness, on the other hand, interplays with the visual perception of spatial orientation (Gabbard, 1992).

Successful performance of virtually all motor skills depends on the individual's ability to establish balance. The new-born must establish vestibular awareness before any of the early developmental motor milestones can be achieved. Kinaesthesia is thus basic to all movement. The kinaesthetic and visual modalities dominate learning and acquisition of motor skills (Gabbard, 1992).

2.3.4 Motor development

The study of motor development involves the study of movement behaviour and the associated biological change in human movement across the life span (Magill, 1993; Lockman and Thelen, 1993). Motor development is therefore a process that begins in the pre-natal period where most movements involve reflexes and continues throughout life (Gabbard, 1992; Owens, 1992). These phases of motor behaviour are set out in *Table 2.3.*

Table 2.3: Phases of motor behaviour

Phase	Approximate age	Stage
Reflexive/Spontaneous Rudimentary	Conception (three months)	Prenatal
	Birth	Neonate
	One month	
	Two months	Infancy
	Six months	
Fundamental movement	Two years	Early childhood
Sport skill	Six years	Later childhood
Growth and refinement	Twelve years	Adolescence
Peak performance	Eighteen years	Adulthood

(Sources: Clark and Allen, 1985; Gabbard, 1992)

With maturation of the central nervous system, neural commands begin to co-ordinate muscles, permitting progressively powerful and refined motor activities. Motor development also shows differentiation (the enrichment of global and relatively diffuse actions with more refined and skilled ones) and integration (increasingly co-ordinated actions of muscles and sensory systems). During the first year infants develop from having reflexive and random behaviours to voluntary actions as they gain neuro-motor control of the head, arms and legs (Owens, 1992; Bukatko and Daehler, 1995). Early movement behaviour can be classified by movement associated with reflexes, progressing to spontaneous behaviour, to postural control, to rudimentary locomotion and to manual control (*Table 2.3*)(Clark and Allen, 1985; Gabbard, 1992; Owens, 1992). Many of the fundamental motor skills (rudimentary) developed during the first two years of life (postural control, locomotion and manual control) continue to be modified and refined during childhood to develop effective co-ordination, balance, speed, agility and power (Gabbard, 1992; Bukatko and Daehler, 1995).

Closely linked to development of manual and overall motor control during childhood is establishment of limb and eye preference, whereas handedness appears to mature earlier (Gabbard, 1992). During later childhood and adolescence improvement in motor skill performance continues and focuses on refinement of skills.

2.3.5 Language development

"Language is a multi-faceted skill with many overlapping dimensions, from understanding and uttering sounds to appreciating the sometimes subtle rules of social communication "(Bukatko and Daehler, 1995:247). Therefore, understanding language development is essential in order to understand the development of the child in its environment as this skill is closely linked to the development of cognitive processes, socialisation and academic learning skills (Bukatko and Daehler, 1995).

Specialised physiological systems are responsible for the processing of human language and set the predisposition to be responsive to language features. Most babies are born with communication potential and have some foundation skills (Nelson, 1993). Language development in children occurs spontaneously and in a short space of time (a span of about four to five years) children develop complex linguistic systems. Linguistic communication development during the first year of life starts at birth where communication intention is inferred by the adult and develops through active exploration of the environment to the point where the infant shows communication intentions using gestures and vocalisations (Owens, 1992; Nelson, 1993). This first contact with speakers is important as can be seen in instances where children who were deprived of human communication and language models subsequently did not develop any language (Akmajian, et al., 1992; Owens, 1992; Nelson, 1993).

A long period of reception of auditory language symbols is the prerequisite for later language formulation. Early listening is not a passive process, but one in which the infant participates by responding to some important elements of human speech to prepare him/her for language performance (Northern and Downs, 1991; Meyer, 1993; Bukatko and Daehler, 1995). The infant discovers phonetic meaning by discovering the commands required by its own vocal tract to match the output of the auditory template formed during early listening experience. Perceptual skill precedes motor skill (Akmajian, et al., 1992). Changes in the child's speech productive capabilities are also linked to physiological changes in the vocal apparatus as well as the central nervous system during the first year of life (Owens, 1992; Bukatko and Daehler, 1995).

Children pass through a series of recognisable stages as they master their native language. A general characteristic of semantic development is that children comprehend (receptive language) far more language than they are able to produce (expressive language). This manifests itself in the phenomenon that gestures used for communication usually precede words by a few weeks (Akamajian, et al., 1992; Owens, 1992; Bukatko and Daehler, 1995). Dramatic accomplishments concerning acquisition of the grammatical code take place during the pre-school and early elementary years in the areas of language form, expansion of concepts (language content) and language use. By the age of five years most children are highly proficient listeners and speakers and have acquired eighty percent of the syntactic structures used by adults (Owens, 1992; Nelson, 1993).

The knowledge gained by studying language development enables researchers to view language development as a part of a larger concern. Important in this respect is that language development is parallel to cognitive development (Owens, 1992). The child's cognitive growth assists in the acquisition process and the child must filter spoken language to create general rules for language use. Caregivers also provide models of correct speech and provide feedback as to the correctness of the child's language use (Owens, 1992; Nelson, 1993).

Little is still known about the development and/or representation of cortical language organisation in children. Knowledge of language acquisition and use and theoretical perspectives on neuro linguistic development are still evolving (Campbell, 1993; Cacace and McFarland, 1998).

2.4 MULTIMODAL PERCEPTION

The relationship between the senses is a subject which has been discussed since the ancient Greeks; as is the importance of the meaning of this relationship for perception and cognition (Abravanel, 1981; Lewkowicz, 1994). To study the mechanisms of inter-sensory perception is to go back to the fundamental questions of attention, perception and learning (Abravanel, 1981). Perceptual and perceptual-motor processes frequently involve the simultaneous use of more than one system; this is inter-sensory perception. Perceptual integration therefore includes the translation of information from one sensory modality into another (Gabbard, 1992). Thus, the co-ordination of sensory information to perceive or make inferences about the characteristics of an object refers to inter-modal perception (Bukatko and Daehler, 1995).

Multi-modal perception can be defined as the neurological process of transferring sensory data received through one input modality to another system along the nervous system (Nicolosi, et al., 1989). *Figure 2.5* gives an outline of the general information-processing model depicting multi-modal perception (perceptual-motor model)(Gabbard, 1992).

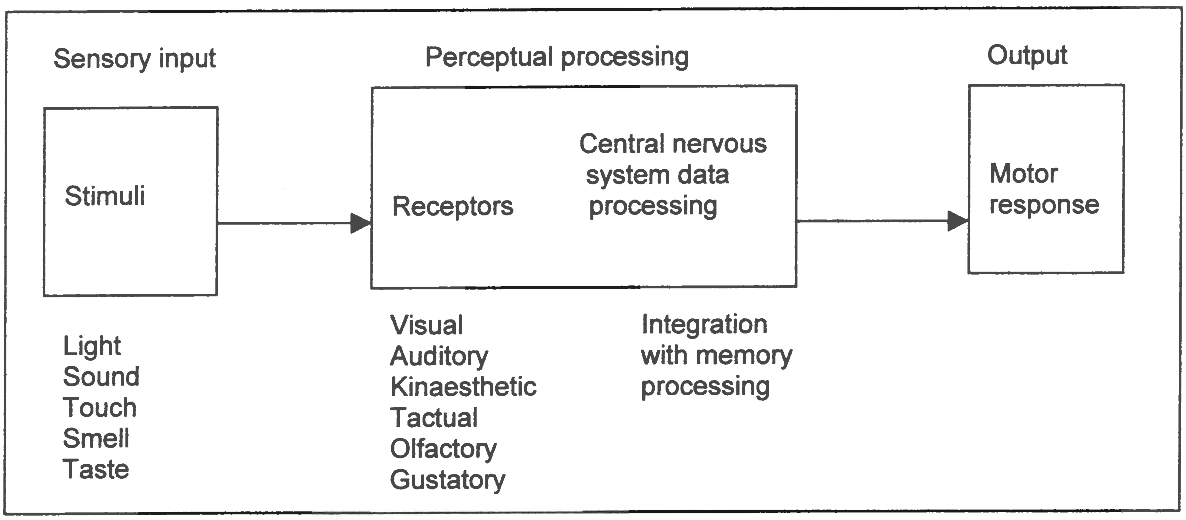


Figure 2.5: The general information-processing model (Gabbard, 1992: 153)

Perceptual structures, nevertheless, do not have the same theoretical status as objective knowledge; "to perceive" is not synonymous with "to know". Information may be detected in perception, but can be overruled by objective knowledge (Butterworth, 1981). Sensory, perceptual and cognitive processes can be viewed as lying along an uninterrupted sequence continuum where any strict division would be difficult with present knowledge in the relevant literature (McFarland and Cacace, 1995).

In the past two opposing schools of thought were prevalent in the matter of the obtaining of knowledge of the sensory pathways of the central nervous system. These were on the one hand the conceptual and experimental isolation of the senses and on the other hand the approach where no modality distinction is made (Jones, 1981). However, researchers now recognise that no sensory modality is completely isolated from any other. No sensory exercise is free from repercussions on other sensitivities (Bloch, 1994).

As described in section 2.2, from the view point of neuro-physiology, it is clear that sensory systems have diffuse projections. At higher levels of the nervous system space is represented by overlapping and integrated inputs from a number of different modalities (Jones, 1981).

According to Ayres (1983) inter-modality association occurs at all levels and also involves non-sensory processes of memory and reasoning at higher levels. It is no longer appropriate to think in terms of isolated sensory modality development of function. The brain functions as a whole and one of its attributes leading to wholeness is its manner of converging sensory input. A great deal of the integration occurs at brainstem and thalamic levels, which then influences integration at higher levels. This process of multi-sensory filtering, summation and convergence is a more effective way of functioning (Ayres, 1983).

The literature is replete with examples in which information in one sense changes perception in another. For example, a visual cue can significantly alter judgements about proprioceptive and auditory cues, and proprioceptive cues can bias judgements regarding the location of an auditory cue. It is because the sensory systems have evolved to work synergistically that misperceptions occur when the cues they provide conflict with another stimulus (Stein, Meredith and Wallace, 1994). Interesting findings in synesthesia illustrate that this cross-modal perception which reveals that similarities between, for example, pitch and brightness or chromesthesia (coloured hearing synesthesia) which may take place at a sensory/perceptual level of processing result from strong cross-modal associative ability (Marks, 1987; Rizzo and Eslinger, 1989; Stein, et al. 1994). Understanding multi-modal interactions is therefore essential for understanding perception, action, learning, and development (Bedford, 1994; Stein, et al.,1994).

The practice of studying behavioural change in an integrated multidisciplinary approach has emerged. Behaviour in any domain (for example, cognitive, affective, psychomotor) is the product of many influences. To have a fuller understanding of human development, one should consider the full range of possible influences (total-development perspective)(Gabbard, 1992).

2.4.1 Development of multi-modal perception

At any moment in time, a variety of sensory stimuli invades the senses. The developing infant must learn to determine how these sensory inputs relate to one another and learn to organise the peripheral stimuli to make sense of the external world. Although our senses separately code information about properties of a stimulus, most events in the environment provide for multi-modal stimulation. Detection of cross-modal correspondences is essential to the experience of a unified world and the ability to draw inferences about environmental events and then act efficiently upon these events (Morrongiello, 1994).

The existence of specialised sensory systems provides a means of dissociating stimuli by modality and the convergence of different inputs in the central nervous system provides a mechanism for identifying related events (Stein, et al., 1994). It is suggested that the substrate for some form of inter-sensory interaction is established pre-natally. This is consistent with neuro-anatomical findings (Stein, et al., 1994).

A degree of relationship between the senses may be necessary for any kind of development to take place. The functional properties of inter-sensory and sensorimotor organisation may form the basis for detecting multimodal properties of objects for the acquisition of motor control, and may form part of the underpinning for cognitive constructs (Butterworth, 1981). Cross-modal development is intertwined with cognitive development (Abravanel, 1981; Bushnell, 1981). Perceptual development consists of learning to attend to the most relevant features and relations of objects and events; of learning how to explore in order to canvass global information and to pick up more precise data. As these functions of perception develop, the child becomes a more precise and specialised perceiver who is capable of making more differentiated and accurate judgements (Abravanel, 1981).

2.4.1.1 Philosophical views of multi-modal development

The debate in the literature centres around the original philosophical issue of whether inter-sensory co-ordination develops as a function of experience or whether it is in some sense innate. Intersensory development is framed in the literature in terms of two opposing theoretical views:

- the differentiation view (ecological approach). According to Gibson (in Gabbard, 1992) inter-modal perception is innate and individuals can directly perceive information that exists in their surroundings. Infants have powerful perceptual capacities from birth and with experience become increasingly aware of their surroundings resulting in greater perceptual refinement (Gabbard, 1992). This line of thought as advocated by Bower, Gibson and others (in Abravanel, 1981 and Bushnell, 1981; Lewkowicz, 1994; Morrogiello, 1994; Stein, et al., 1994; Bukatko and Daehler, 1995) suggests that the senses at birth are not differentiated from one another, but an a-modal unity of the senses and the infant's perception is "supra-modal",

- in the integration view (constructivist approach); on the other hand, are those for example Piaget, Helmholtz and Berkeley (in Bushnell, 1981; Lewkowicz, 1994; Morrongiello, 1994; Stein, et al., 1994)) who maintain that during the early stages of infancy the various perceptual systems are independent and development is a process of integration due to enrichment.

This debate on innate versus acquired, or maturation versus learning, has long since proved to be something of the past (Butterworth, 1981). Bushnell (1981) believes that both these views are applicable. In her model, both Piaget's process of integration and Bower's process of differentiation are part of cross-modal development. Development ranges from effecting conditioning in the early months to higher-level processes in the later stages of development. Along similar lines is the intensity hypothesis of Lewkowicz (1994). He postulates that inter-sensory responsiveness during early development is constituted by the fact that, during the first few months of life, the infant's responsiveness to stimulation in all modalities is dominated by the quantitative aspects of stimulation. After this initial period, responsiveness to the qualitative aspects of the stimulus emerges. An explicit assumption of the intensity hypothesis is that both integration and differentiation processes are involved in the development process that leads up to the emergence of these more advanced response mechanisms (Lewkowicz, 1994). The emergence of different inter-sensory perceptual capacities at different points in development, and the role that the earlier ones can play in the emergence of the later ones, can be best understood in terms of viewing development as a set of complex epigenetic interactions between the external environment and the child (Lewkowicz, 1994). Substantial evidence exists to support this role of experience in inter-modal development (Bukatko and Daehler, 1995).

2.4.1.2 Development of perceptual integration

Like adults, new-borns are exposed to a multi-modal environment. The infant has already been in this type of environment before birth (sounds, odours and tastes are part of the uterine world). All the sensory systems are functional when the foetus is born at term. Therefore, more than one modality is involved in the new-born's actions, although all the sensory systems are relatively immature at birth. Although sensory systems develop at different rates (Bloch, 1994), there is compelling evidence of developmental dependencies between sensory modalities (Bloch, 1994; Quittner, Smith, Osberger, Mitchell, and Katz, 1994).

Intersensory perceptual integration is at least partially functional at birth and improves with age beyond the childhood years. Three basic levels of inter-sensory integration can be observed, namely:

- the automatic integration of basic information as a function of the sub-cortical brain. This level is inherent in nervous system processing and is functional at birth or shortly thereafter,

- the recognition of a specific stimulus or the features of a stimulus as the same or equivalent when they are presented to two different perceptual modalities. This is often referred to as cross-modal equivalence. This ability is also present in new-borns,
- the cross-modal concept which involves the sophisticated transfer of concepts across perceptual modalities. This function requires the inter-relating of certain cognitive dimensions and may be used to solve problems that are associated with dissimilar yet related sensory input that has been presented through two different modalities. This type of behaviour is usually found in children of five years and older (Gabbard, 1992).

In very young infants, the introduction of a sound results in increased visual activity and attention, suggesting early links between auditory and visual processing. Links between auditory and visual spatial processing may also be present at birth and function similarly throughout the life cycle (Morrongiello, 1994). Evidence exists that hearing plays an important role in the development of visual attention (Quittner, et al., 1994).

Links between auditory and visual events can also be seen in an infant matching auditory and visual cues and attention given to match visual stimuli when accompanied by sound (Lewkowicz, 1994; Bukatko and Daehler, 1995). For instance, speech perception is also greatly affected by what a person sees. Experiments with babies of five months of age, confirm this audio-visual correspondence to be present early in life (Kuhl, 1987; Green, Kuhl, Meltzoff and Stevens, 1991; Kuhl and Melzhoff, 1992; Lynch, et al., 1992). Furthermore, speech perception relies heavily on simultaneous processing of auditory and visual information (Meyer, 1993).

The understanding of language is a form of pattern recognition involving the evaluation and integration of multiple sources of information and is influenced by many sources of information. An example is the use of visual and auditory information in face-to-face speech. This results in human recognition of speech to be robust because there are usually multiple sources of information that the perceiver evaluates and integrates to achieve perceptual recognition (Kent, 1992; Massaro, 1994).

Observable behaviour that reflects learning that depends on visual perception, includes gross motor skills, fine motor abilities, play, speech, and certain academic tasks (Kramer and Hinojasa, 1993). For example, the normal academic task of learning to read aloud requires visual, auditory and motor integration (Gabbard, 1992). Furthermore, the development in cognition and motor skills in a combined form is necessary for perceptual tasks such as reading (Bukatko and Daehler, 1995). In speech development, auditory-motor equivalent classification can be seen in infants when they imitate other speakers. Inter-modal perception of speech also points to a cognitive aspect used by the infant to obtain information of the environment. (Kuhl, 1987).

Multi-modal perception also plays a role in action, where all sensory-motor co-ordination includes inter-modal co-ordination. Two learning processes are relevant here (Bloch, 1994), namely:

- feedback effects exist where perception influences action as a feedback. No correction of movement can be expected when the act is performed, and correction can only take place from trial to trial,
- feed-forward effects exist where perception guides the movements step-by-step during execution.

A number of researchers (in Bloch, 1994) favour this pro-active role of perception from birth onwards. "Infants first act to know, then act because they know" (Bloch, 1994: 326). The first form of sensory-motor co-ordination appeals to vision as a prime modality for goal specification in space. The second form of co-ordination testifies to multi-modal perceptual knowledge, determining verifications through action (Bloch, 1994).

From the above discussion, it can be seen that perceptual and perceptual-motor processes frequently involve the simultaneous use of more than one sensory system. All sensory systems in humans are complex and they are composed of different sub-systems, which carry out several functions (Bloch, 1994).

2.5 IMPLICATIONS OF THE THEORETICAL FINDINGS RELATED TO CENTRAL AUDITORY PROCESSING, LANGUAGE ABILITY, SENSORY INTEGRATION AND LEARNING DISABILITIES IN SUPPORT OF THE HOLISTIC APPROACH

The inter-dependency of the different modalities has far-reaching implications for approaching central auditory processing disorders, language disorders, learning difficulties and sensory integration dysfunction, as can be seen in the vast amount of acknowledged studies done in this respect (list of references in Appendix A). The role of sensory integration problems on the functioning of other modalities is however not so widely acknowledged. The foregoing abbreviated discussion of the neuro-physiological and developmental integratory properties of the sensory systems explains the relationship between central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction. *Figure 2.6* is a representation of possible problems present in a child with a developmental learning disorder and the relationship that can exist between central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction. The complexity of the developmental learning disorders (viewed with emphasis on the role of the auditory processing system) can be seen in several of the examples set out in *Figure 2.6*.

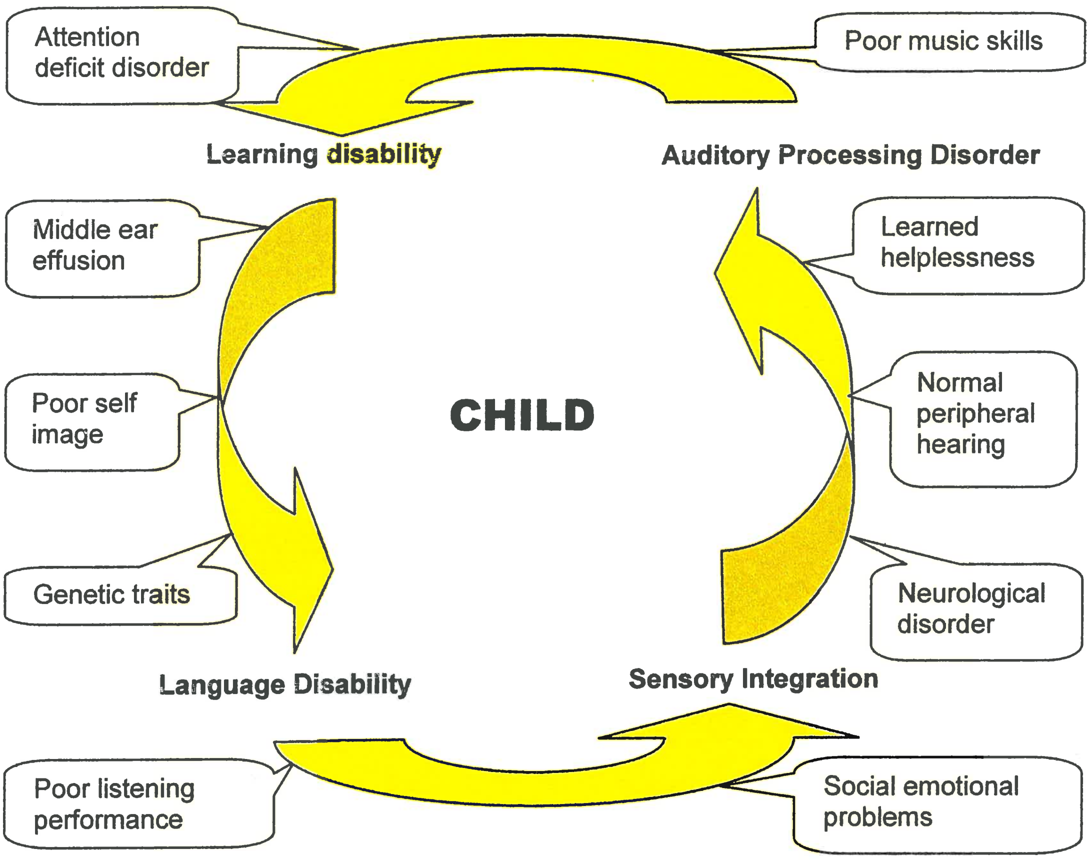


Figure 2.6: Representation of examples of different aspects present in children with developmental learning disorders. Information obtained from: Keith and Stromberg, 1985; Keith, 1988; Musiek, et al., 1990; Smorski, et al., 1992; Sloan, 1998.

Acquisition of an oral language depends on the processing of acoustic information. Whatever the central mechanisms may be that enable children to learn oral language with rapidity and ease, they require auditory processing of spoken language input. Central auditory processing disorders are therefore linked to developmental language disorders (both receptive and expressive language) (ASHA, 1996; Sloan, 1998). Children with a language impairment have difficulty in temporal processing, processing of rapidly changing acoustic signals and fine-grained auditory discrimination (Elliott, Hammer and Scholl, 1989; Robin, Tomblin, Kearney and Hug, 1989; Elliott and Hammer, 1993; Helzer, et al., 1996; Kraus, et al., 1996; Merzenich, Jenkins, Johnston, Schreiner, Miller and Tallal, 1996; Tallal, Miller, Bedi, Byma, Wang, Nagarajan, Schreiner, Jenkins and Merzenich, 1996). It can thus be said that children with specific language disabilities have underlying central auditory processing disorder problems (Sloan, 1986; Riccio, et al., 1994).

Thus, central auditory processing disorder at an early age, when language is just beginning to develop, results in severe language disorder as the normal auditory route to language learning is hampered and the brain cannot develop the capacity to process language (Gordon and Ward, 1995). Important to note is that the eventual comprehension of a spoken utterance depends on much more than the processing of acoustic signals. The listener must not only identify, or estimate, the acoustic aspects of the signal, but must also interpret its linguistic value.

Another dilemma existing in pre-school children is that the relationship between language and central auditory processing is such that it is difficult to distinguish between auditory processing disorder, language impairment or higher order cognitive processing disorder (Hurley and Singer, 1985).

Auditory tasks are also influenced by higher level, non-modality-specific factors such as attention, learning, motivation, memory, and decision processes (ASHA, 1996). Central auditory processing disorders can also be related to the high incidence of poor performance on verbal and non-verbal auditory perceptual tasks, as well as tests of visual, temporal and tactile perception in children with language disabilities (Bernstein and Stark, 1985). Studies providing the evidence showed that children with a language disorder are slow in the development of auditory, visual, tactile, phonetic and dihaptic perception skills as well as on motor tasks. This suggests a general neuro-maturational delay (Welsh, et al., 1996; Cacace and McFarland, 1998). Studies done by Elliott, et al., (1989) and Elliott and Hammer (1993) suggest that auditory skills are important for developing basic competencies important for language learning and school success. This indicates the important connection between speech-language delay and/or impairment on the one hand and on the other hand later academic-related problems (Riccio, et al., 1994; Gordon and Ward, 1995; Sloan, 1998).

Most new information presented to children in the classroom is via the auditory channel (Musiek and Lamb, 1994; McSporran, 1997) and the processing of this information is a complex process. Most children with learning disabilities present with central auditory processing disorders (Musiek and Lamb, 1994; Chase, 1996; Cacace and McFarland, 1998). The linguistic, cognitive and social knowledge involved in the listening process influences children's ability to construct meaning from the sounds that they hear (McSporran, 1997). In other words, it is necessary for children to have sufficient listening skills to develop the meta-linguistic and sophisticated linguistic skills central to the academic process (McSporran, 1997).

An important fact is that children with learning disabilities and/or language disorders are a heterogeneous group whose problems involve information-processing problems that are not typically restricted to a single sensory modality (Tallal, Stark, Kallman and Mellits, 1981; Cacace and McFarland, 1998; Bellis and Ferre, 1999). Results of studies underline the auditory basis of dyslexia where people with dyslexia perform poorly on commonly used behavioural audiologic tests (Cacace and McFarland, 1998; Hugdahl, et al., 1998). However, studies also suggest that children with developmental dyslexia have problems in processing that are not restricted to one sensory modality. There is evidence that poor readers can have problems in both visual and auditory processing and, furthermore, that dyslexia also has a compelling linguistic basis (Willeford, 1985; Chase, 1996; Cacace and McFarland, 1998). Poor performance on tactile measures and difficulties in motor sequencing skills in children with dyslexia are also found (Ayres, 1983; Felmingham and Jakobson, 1995; Moore et.al. 1996). It can thus be said that some children with learning disabilities do have a central auditory processing disorder, and if such deficits also present in other sensory modalities these can be seen as multiple disabilities.

It appears that central auditory processing affects the capacity to attend and think, and that these cognitive processes somehow involve the auditory pathways (Bench and Maule, 1997). It is however not exactly clear how academic underachievement relates to complex interactions between a child's neuro-psychological base and cognitive, linguistic and psychosocial problems (Bernstein and Stark, 1985; McSporran, 1997).

Another aspect of importance is that children with central auditory processing disorders are often characterised as being hyperactive, inattentive and having a short attention span (Chermak and Musiek, 1992; McFarland and Cacace, 1995). It is also suggested that children classified as having a central auditory processing disorders may actually have attention deficit disorder, because of the similarities of characteristics existing in both disabilities (Keller, 1992; Riccio, et al., 1994, Musiek and Chermak, 1995; Cacace and McFarland, 1998; Chermak, et al., 1999). Information from studies however suggests that the basis for attention deficit disorder is found not only in the encoding of auditory sensory stimuli, but also involves other modalities and skills (Hall, Baer, Byrn, Wurm, Henry, Wilson, and Prentice, 1993; Cacace and McFarland, 1998; Chermak, Somers and Seikel, 1998; Sloan, 1998; Chermak, et al., 1999). It is important to bear in mind that disorders of attention are complex and controversial, where the term attention refers to many psychological processes, some modality specific and others not (Keller, 1992; McFarland and Cacace, 1995).

Children which were auditory deprived by otitis media in early life are expected to have an auditory specific deficit, but deficits in these children may not be restricted to one sensory modality and can also involve visual and gross-motor skills (Cacace and McFarland, 1998). These children also manifest problems in verbally based learning that leads to language and phonological deficits (Roeser and Downs, 1988; Menyuk, 1992; Campbell, 1993, Cacace and McFarland, 1998). Integration of multi-modal sensory information is necessary for attentional development and the presence of otitis media may adversely affect attention, and thus academic skills (Cacace and McFarland, 1998). Another study where auditory specific deficits may be anticipated is a study by Quittner, et al., (1994) on hearing children, deaf children with cochlear implants and deaf children without cochlear implants. They found that a history of experience with auditory stimuli is important in the development of visual attention. They suggest that directing, engaging, and disengaging attention seems to rely on multi-modal processes.

However, because of the heterogeneous nature of children with learning disabilities, it is possible that the underlying pathologic mechanism is neither specific nor consistent (Welsh, et al., 1996). Using the medical model (discussed in section 1.2.1.5) it is better to refer to central auditory processing disorder as a developmental disorder when no clear organic pathology is evident, than as a disease, because the aetiology or site-of-lesion is not always clear. A developmental approach seems to support the conclusion of some researchers that language disorders cause central auditory processing disorders (Rees in Northern and Downs, 1991).

Given the fact that deficits such as central auditory processing disorders, dyslexia, attention deficit hyperactive disorder and language disorders are heterogeneous entities which show problems typical of involving more that one sensory modality, it is likely that a sensory integrative approach will be beneficial (Felmingham and Jakobson, 1995; Cacace and McFarland, 1998; Bellis, 1999). Care must however be taken not to refer to central auditory processing disorder and learning disability, interchangeably, and caution should be exercised with the relationship between learning disabilities and central auditory processing disorders (Matkin and Hook, 1983; Sanger, et al., 1987; Katz and Ivey, 1994; Bellis, 1996). To determine the contribution of one deficit on another, the whole child must be taken into account and the identification process must reflect this interdependency (Bellis, 1996; Welsh, et al., 1996). A multi-disciplinary approach to identifying these children will aid in early identification of children with developmental learning disorders in order to determine the modalities involved and reduce inappropriate diagnosis (Sanger, et al., 1987; Bellis, 1996). Accurate determination of the underlying dysfunctional processes will yield appropriate recommendations for management.

2.5.1 Implications for assessment of and intervention in developmental learning disorders

The most important consideration in viewing a child with developmental learning disorders holistically and acknowledging the interrelationship between the senses and the effect on developmental processes, is the planning and implementing of assessment strategies and management programmes. The following discussion gives examples of aspects which are important in assessment and management of children with central auditory processing disorders.

Analysing the nature of a child's problems can be conceptualised as a series of hypothesis testing sequences. Assessment has two objectives, namely to determine an appropriate diagnosis and to determine intervention (Maag and Reid, 1996). In determining diagnosis, it is important to identify the true nature of the problem in order to assist in assessment and management. More specifically, it is necessary to determine if the child has a multi-modal deficit (where the central auditory processing disorder may be part of larger general processing difficulties) or if the problem is limited to one modality (for example an auditory specific deficit)(Battin, 1988; McFarland and Cacace, 1995; Cacace and McFarland. 1998).

Because of the individuality of brain organisation and the pathologies that affect such organisation, central auditory processing disorders can affect individuals differently. An individual approach must be taken in the selection of assessment measures and the interpretation of their results. Performance on any test can be influenced by a variety of factors such as age, education level, social and cultural background, cognitive ability, use of medication and motivation. Additional aspects such as other sensory modalities involved, motor skills, memory, cognitive, linguistic, and attention demands required to perform the test should also be borne in mind (Stach, 1992; ASHA, 1996; Cacace and McFarland, 1998). Tests of central auditory processing should therefore be supplemented by visual or tactile tasks that are of a nature similar in other respects but differing in sensory modality (Cacace and McFarland, 1998). This approach allows for other than auditory processing difficulties to be present in the same individual and recognises that additional testing in other sensory modalities is required in order to elucidate the diagnosis (Tallal, et al.,1981; McFarland and Cacace, 1995; Sloan, 1998).

Diagnosis of central auditory processing disorders by using modality specific measures is therefore limited (McFarland and Cacace, 1995; Cacace and McFarland, 1998; Bellis and Ferre, 1999; Chermak, et al., 1999) and the use of a test battery is therefore recommended. If only specific patterns of deficits are considered, the uni-modal test battery can reduce false positives (Stach, 1992). To investigate the cause of a child's failure on the central auditory processing tests in a test battery, the use of analogous tests in other sensory modalities will validate the diagnosis, improve reliability and determine interrelations among various tests (Stach, 1992; Watson and Miller, 1993, McFarland and Cacace, 1995; ASHA, 1996; and Cacace and McFarland, 1998; Sloan, 1998; Chermak, et al., 1999).

To illustrate this problem McFarland and Cacace (1995) consider three categories of individuals who perform poorly on specific tests involving the processing of auditory information, namely:

- individuals with specific perceptual problems in processing information presented in the auditory modality (modality-specific perceptual deficits),

- individuals with auditory perceptual problems coexisting with other processing problems (mixed pattern of deficits),
- individuals who perform poorly on tests of auditory processing not because they have auditory-specific perceptual problems, but because the test in question is sensitive to other processing demands such as motivation, attention, memory, and motor skills (supra-modal deficit).

Poor results are understandable if one takes into consideration that it is not certain whether audiologic behavioural tests and linguistically based tests for determining central auditory processing test the same functions and identify the same children, and therefore professionals should include both measures in order to completely evaluate a child's auditory processing abilities at all levels (Sanger, et al., 1990). Regardless of the nature of the processing deficit, most children who have a problem with comprehension of spoken language will profit from both above-mentioned procedures (ASHA, 1996). It is thus appropriate to say that, if it is maintained that certain learning problems result from an auditory-specific perceptual dysfunction, the critical issue is *to determine whether auditory skills are involved regardless of whether these deficits involve language or not*. If, however, processing deficits are demonstrated in multi-sensory modalities, then the diagnosis of a central auditory processing disorder alone is inappropriate and alternative diagnoses need to be considered (Cacace and McFarland, 1998). Appropriate testing should therefore differentiate between cases involving predominantly auditory perceptual problems and cases involving multi-sensory problems and cases involving non-perceptual problems (McFarland and Cacace, 1995).

The purpose of the assessment process is to compile an intervention program that will improve the everyday function and life satisfaction of the child, in other words a plan of action to alleviate or minimise the difficulties present. The importance of early identification is the fact that early intervention is considered to have the greatest impact (Katz and Cohen, 1985; Chermak and Musiek, 1992; Northern and Downs, 1993; Sloan, 1998). Since auditory processing disorders, language disorders and learning disabilities often coexist, this fact can be used for early identification and referrals can be made for appropriate professionals to implement more comprehensive assessment (Sanger, et al., 1987). An important research finding is the connection between early speech-language delay or impairment and later academic-related problems (Sloan, 1998). Evidence suggests that children at risk for communication disorders reveal difficulties in categorical auditory perception and/or integration of visual and auditory information from an early age (Kuhl, 1987; Kuhl and Meltzoff, 1982; Lynch, et al., 1992). The consequent implication is that this phenomenon can be used for early identification of children at risk for a developmental learning disorder. Early identification of central auditory processing disorders with follow-up of intervention can thus prevent development of learning disabilities (Cherry, 1992).

Appropriate intervention should change the child's functioning (Maag and Reid, 1996). Successful treatment also involves intervention aimed at the neuro-physiological level of processing, acknowledging the cognitive components critical for learning to read or acquiring language and determining those neuro-physiological processes that are impaired for a child with learning disabilities. Intervention strategies can then be developed that attempt to correct the neuro-physiological defect and thereby improve cognitive processing and facilitate normal learning (Chase, 1996). Understanding how neuro-pathology affects the processing of sensory and cognitive functions is therefore critical to developing an approach to management that targets the underlying biological defect (Chase, 1996).

Accepting patterns of deficits on multi-test protocols as possible evidence for central auditory processing disorders implies the use of a multi-disciplinary team in assessment and management of children with developmental learning disorders. “A multi-disciplinary approach which takes into account the individual child’s auditory, language, learning, and associated characteristics is critical to appropriate interpretation and management” (Bellis, 1996, p 185),

2.5.2 A Holistic team approach

The advantages of teamwork when working with children with special educational needs are widely acknowledged as discussed in section 1.2.1.7. Teamwork means that the members of a team work together in assessing a child and devise the optimal approach to the intervention plan.

Figure 2.7 illustrates inter- and intra-disciplinary co-operation in a representation of how a human being functions holistically. This model illustrates the different levels of functioning of a human being from the biological level to the level of abstract thinking which incorporates the metaphysical level. The holistic view of a human being requires that all these levels or systems should be incorporated. In the assessment of a child with a developmental learning disorder, an open mind should be kept in accepting input from professionals of a number of disciplines. The information should then be pooled to assess the child and plan an intervention programme.

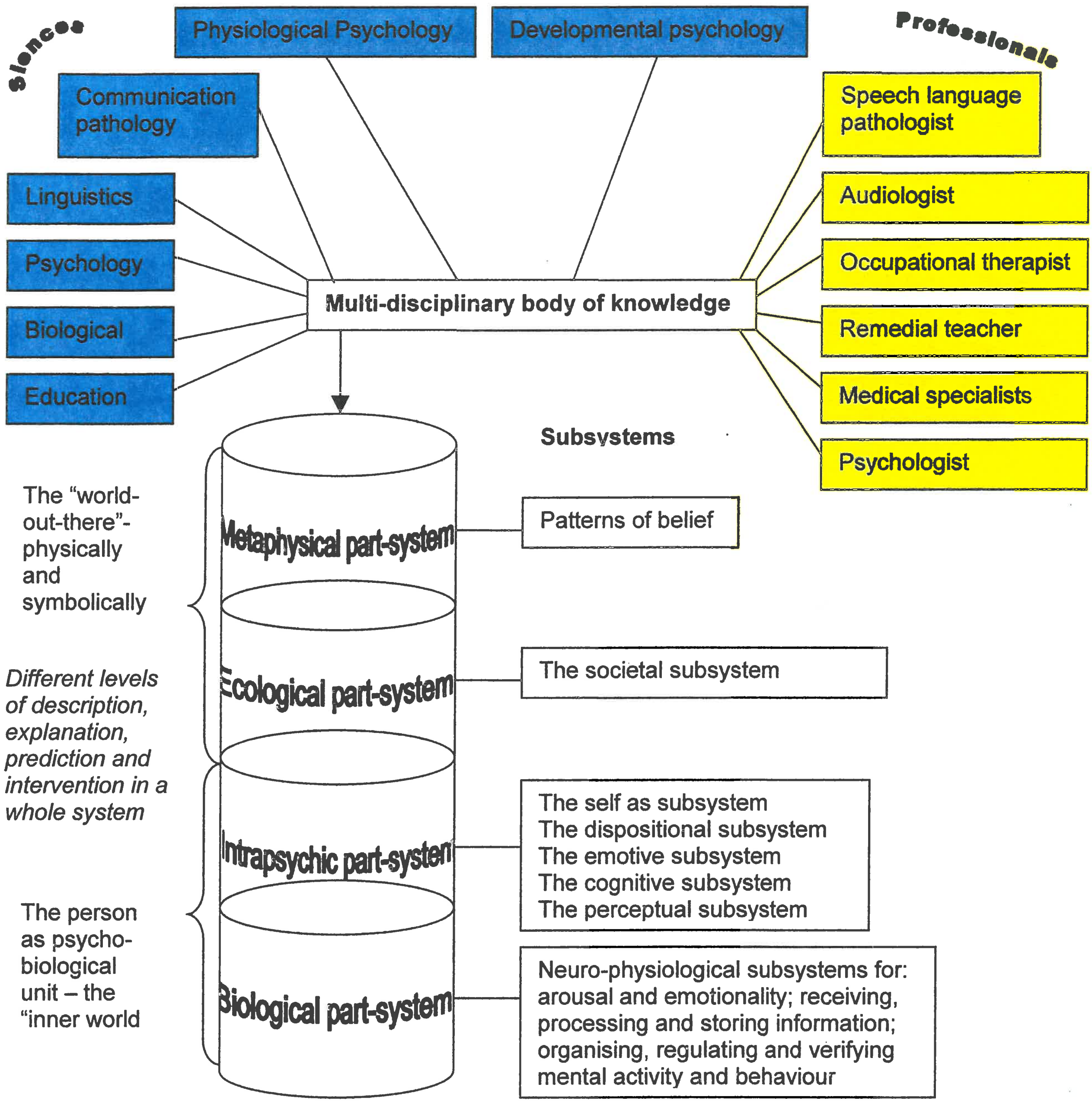


Figure 2.7: Inter- and intra-disciplinary co-operation in the case of developmental learning disorder (Developed from: Jordaan and Jordaan, 1994).

A multi-modal treatment model should be developed that encompasses an individual programme to suit the individual child. This incorporates continuous assessment and ongoing intervention and a systematic management plan to provide an integrated and co-ordinated treatment program. A multi-modal treatment model exists when children are systematically evaluated from a multi-dimensional viewpoint, and a treatment plan is formulated within a single clinical setting. Some authors stress the designation of one person (case manager) to co-ordinate the individual child's program. A multi-modal model requires a serious, long-term commitment of time and effort on the part of all involved parties (Keith and Stromberg, 1985; Maag and Reid (1996).

2.6 SUMMARY

It is clear from the evidence of literature on the neurophysiology of the central nervous system that it functions as a complex system with numerous connections between structures both sub-cortically and cortically. No single sensory system functions in isolation and all sensory systems are also involved in motor function.

This interrelationship of the sensory systems and motor function involved in learning, are further illustrated by viewing the development of the sensory systems, the motor functions involved in learning, and the complex development of human language. To develop language the child must have sufficient functioning of the sensory systems, a functional motor system, and adequate cognitive abilities to interact meaningfully with the environment.

Evidence is also overwhelming that multi-modal perception and holistic functioning of the child are crucial in developing sufficient skills to cope academically.

In viewing a child with developmental learning disorders holistically and taking into account the evidence of the literature, it seems logical to approach a child as an individual being, but one who also functions as a holistic entity, who functions both inter- and intra-modally. This has far-reaching implications for assessment and intervention programmes for children with developmental learning disorders. Consideration of the interrelationship between central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction, justifies and leads to an inter-disciplinary or trans-disciplinary approach when undertaking assessment of a child with developmental learning disorders and planning intervention for such a child.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

In South Africa, a developing country, the majority of professionals working with children with learning disabilities and central auditory processing disorders do not have access to high-technology equipment to assess these children. There is a lack of sufficient manpower and funds in developing countries to meet the need for the provision of intervention for children with developmental learning disorders. At present the majority of professionals evaluating central auditory processing disorders are dependent on linguistically based non-audiological tests to determine central auditory processing disorders (Graz, 1998; Fourie, 1998).

This problem, which motivated this study, has been elaborated in section 1.2. This investigation was based on the assumption that South African professionals in the clinical and educational setting should be able to function efficiently, using cost-effective, low technology assessment tools. It is thus necessary to determine how this can be accomplished.

In chapter 2, the theoretical aspects derived from the literature, along with the implications flowing from the discussion, have been discussed. The aim of this chapter is to describe the methodology of the investigation into the relationships occurring between central auditory processing, learning and language abilities and sensory integration.

3.2 AIMS OF THE RESEARCH PROJECT

The main aim of the study is to determine whether the assessment results obtained by an inter-disciplinary team through the conventional evaluation of the children at a school for remedial teaching can be integrated in such a manner as to determine the nature of the relationship between central auditory processing disorders, learning disabilities, language disorders and sensory integration dysfunction and thereby facilitate effective diagnosis and intervention on the basis of a unifying holistic model.

The sub-aims of this study are:

- to determine the statistical patterns of existing assessment results by using frequency incidence factor analysis to determine correlation by means of graphical presentations (Leedy, 1993),
- to determine symptom subgroups through the use of phylogenetic analysis of the results (Pagel and Harvey, 1988; Felsenstein, 1993),
- to relate the resulting symptom patterns based on the theoretical neuro-physiological explanation and developmental patterns in order to develop a model through which children with developmental learning disorders can holistically be approached, using conventional linguistically based assessment results to plan an intervention programme.

3.3 RESEARCH DESIGN

The study can be described as consisting of three components.

Firstly, as a case and field study (Leedy, 1993), where data were gathered from the individual subjects to determine characteristics and relationships of data. This was divided into a pilot and a main study and consists of using the existing assessment results of conventional assessment protocol used by the different members of the assessment team at a school for remedial teaching for the purpose of determining patterns of correlation.

Secondly, the research design for the study was then developed into a multivariable correlation ex post facto quasi-experimental design, using statistical descriptions and using no control group but only subjects from a pre-selected group. This method seeks the solution through analysis of data (Leedy, 1993). The need, however, existed to obtain additional insight into the results to explain the nature of the relationships found in the analyses.

Thirdly, the study then developed into a descriptive survey (Leedy, 1993) where the statistical descriptions were discussed in the light of the theoretical neuro-physiological evidence in the literature to provide a means to determine and justify the nature of the results obtained by the conventional statistical (discussed in section 3.6.3.1) and phylogenetic analyses (discussed in section 3.6.3.2). The study describes conventional descriptive statistics showing frequency of occurrence of problems, as well as phylogenetic analyses, which provide a description of the nature as well as of the frequency of occurrence of different problem areas, whilst taking into account the background information discussed in Chapter 2.

Table 3.1 provides an outline of the research design methods as discussed in the foregoing text.

Table3.1: Phases of the research design

Research design	Method	Aim
Case and field study	Gathering of data of existing results of assessments from the school files: • Pilot study • Main study	To determine characteristics and relationships of data
Multivariable correlation ex post facto quasi-experimental design	Analyse and present statistical results of data from a pre-selected group with no control group	To provide a visual presentation of the relationships existing in the data
Descriptive survey	Discussion of statistical results in view of theoretical neuro-physiological evidence in view of: • conventional frequency incidence correlation statistics • phylogenetic analyses.	To justify assumptions made to suggest a model of diagnosis and intervention

3.4 SUBJECTS

The subjects included in the main study consisted of a group of children attending a school for remedial teaching for children with learning disabilities but with normal cognitive abilities. The particular school was selected as, in addition to the fact that all the pupils attending the school fell into the group of children with developmental learning disorders, reliable records did exist at the school. Because a team approach is followed at the school all the data needed for the study were readily available.

3.4.1 Subject criteria

In accordance with the central theme of this research, candidates for this study were required to belong to the group of children with developmental learning disorders which include central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction.

The subjects were required to meet certain criteria relating to learning disabilities, language ability and peripheral hearing, as discussed in the following sections.

3.4.1.1 Learning disabilities

Criteria for the inclusion of subjects, based on the central theme of the study, is that the subjects should be children with learning disabilities, and therefore a school for remedial teaching was selected. Only children with learning disabilities but with normal cognitive abilities are admitted to the school. A child should therefore present with a learning disability indicated by previous academic failure, as identified by teachers involved with the child: these conditions recommend possible admission to the school. An assessment by a team of professionals to establish whether or not a child falls into the category of learning disabilities as required by the school, determines admission to the school. In the case of a pre-school child, the child should present with a possible learning disability, predictable from the assessment results of the battery of assessment tools (Appendix B). The assessment is done by the school prior to admission. *The subjects thus have learning problems which are not primarily the result of visual, hearing or motor disabilities, of cognitive disabilities, of emotional disturbance or of environmental, cultural or economic disadvantage* (Nicolosi, et al., 1989).

The definition of learning disabilities, which is used by the school for admission of children to the school, also requires normal cognitive abilities (this definition is stated in section 1.3.3). All children are tested by a psychologist to determine cognitive abilities as part of the assessment battery performed prior to admission to the school. Intelligence quotients are determined by the Junior South African Individual Scale (JSAIS) designed for children between three years nought months and seven years eleven months and the Senior South African Individual Scale (SSAIS) designed for children between seven years nought months and sixteen years eleven months. Their full-scale intelligent quotients range from 87 to 122. Although this is a wide range, all the subjects fall in the group considered to have average cognitive abilities, this is, an intelligence quotient of between 80 and 89 is considered to be low average, between 90 and 109 to be average and between 110 an 119 to be high average (Van Eeden, 1992). The research subjects therefore have cognitive abilities within the normal range.

The definition of learning disabilities as discussed in section 1.3.3 also excludes serious emotional disturbances. This aspect is assessed by the psychologist prior to admission to the school and it can therefore be assumed that should any emotional problems exist, they are not pathological.

3.4.1.2 Language ability

A criterion for inclusion of subjects for the study is *adequate competence in English*, primarily because standardised tests for central auditory processing abilities are readily available in English. The school used in the investigation is an English medium school and teaching and therapy are conducted in English. Although the school expects competence in English, several of the research subjects were non-mother tongue

English speakers. This is, however, typical of the South African situation and research should therefore include these children. Although this factor could affect the language ability assessment results it was nevertheless decided to include these children to determine from their results and progress whether the underlying language difficulty could be described as a language difference or a language disorder (Nelson, 1993).

3.4.1.3 Peripheral hearing

Normal peripheral hearing was a criterion for inclusion of subjects, because this is a prerequisite for the diagnosis of a central auditory processing disorder (Keith, 1988; Jerger, et al., 1987; McFarland and Cacace, 1995; Cacace and McFarland, 1998). The school is regularly visited by staff and students of the Department of Communication Pathology of the University of Pretoria who administer peripheral hearing tests. From the information obtained in the school files the children selected as research subjects have peripheral hearing within normal limits (pure-tone pass of the screening test of 20dB HL at 500, 1000, 2000, and 4000 as recommended by ASHA in 1985 (in Roush, 1992)).

3.4.2 Subject selection procedures

For this study, nineteen children were selected. The number of subjects included meets the criteria required by the phylogenetic analysis method (Pagel and Harvey, 1988; Hillis, Bull, White, Badgett and Moloneux, 1992; Felsenstein, 1993; Pagel 1999). The method of random selection was employed, using the simple convenience sampling method (Leedy, 1993). Children with surnames starting with A, B, C and D were included. Initially the intention was to include a larger sample of subjects (all the pupils attending the school), but, after a trial analysis (with ten subjects) to become conversant with phylogenetic analysis, it became clear that a large group was not required. Furthermore, the inordinate amount of time required by the multiple phylogenetic analysis would be impractical. This led to the decision to limit the number of subjects.

3.4.3 Description of subjects

Table 3.2 provides an outline of the nature of the nineteen subjects as obtained from the school files.

Table 3.2: Description of the variables present in the nineteen subjects

Subject variables	Description
Gender	Five girls Fourteen boys
Age	Between four years four months and nine years seven months for evaluation prior to admission to the school Between five years eight months and twelve years six months for the most recent evaluation.
Intervention	Remedial education Speech and language therapy Occupational therapy Specific remedial teaching
English second language	One Italian Four Afrikaans
English first language	Fourteen
History of high-risk factors	One Williams' syndrome One haemolytic streptococcal septicaemia Three premature birth Eleven otitis media

The subjects receive remedial education following the mainstream curriculum at the school, as well as speech and language therapy, occupational therapy and remedial teaching with resident professionals during school hours.

3.5 MATERIAL AND EQUIPMENT.

Several professionals are members of the assessment team at the school. The team involved with the initial assessment before admission to the school consists of communication pathologists, occupational therapists, remedial teachers and a psychologist. Follow-up assessments to determine progress in therapy are conducted every six months. Assessments to determine academic progress are also conducted every six months by a remedial teacher. These were the data of interest to the investigation. Although formal assessment tools are used the exact tests used and the exact scores obtained are not always reflected in the file records. This fact influenced certain decisions which were made regarding choice of procedures and data material (discussed in section 3.6).

Each child's school file was analysed to identify specific data, which were entered into a spreadsheet, using the Microsoft Excel computer program. This formed the basis of the procedures which followed. This sheet contained the following information; name, date of birth, intelligence quotient, date of admission evaluation, date of most recent evaluation, medical history, medication, dominance of eye, ear, hand and foot, mother tongue other than English. The problem areas on the spreadsheet were evaluated in terms of whether a problem was present (yes being 1) or absent (no being 0) and entered as such. Problem areas included were auditory memory, auditory discrimination, auditory sequencing, auditory blending, auditory closure, auditory analysis, language reception, verbal expression, concentration, tactile defensive, sensory integration, balance, bilateral integration, eye movement, fine motor abilities, body awareness, motor planning, visual motor integration, visual motor co-ordination, spatial perception, figure-ground perception, visual closure, form constancy, higher cognitive processes and emotion.

Two sets of data were entered for the problem areas, namely, the data for the admission evaluation and the data for the most recent evaluation, in order to obtain data to indicate progress.

Table 3.3 briefly describes the terms employed in the measurement of each problem area.

Table 3.3: Description of problem areas under investigation (Sources: Nicolosi, et al., 1989; Fisher, et al., 1991; Royeen and Lane, 1991; Gabbard, 1992).

Problem area	**Description of the ability/disability**
Auditory memory	Assimilation, storage and retrieval of auditory input
Auditory discrimination	Ability to discriminate between words and sounds that are acoustically similar
Auditory sequencing	Ability to store and recall auditory sequences of different length or number in exact order
Auditory blending	Ability to synthesise isolated phonemes into words
Auditory closure	Ability to understand the whole word or message when part is missing
Auditory analysis	Ability to identify phonemes or morphemes embedded in words
Language reception	Ability to understand spoken language
Verbal expression	Ability to express language orally
Concentration	Active selection of certain stimuli or aspects of experience, with constant inhibition of all others
Tactile defensive	Aversive or negative behavioural responses to tactile stimuli that most people find to be non-painful

Problem area	Description of the ability/disability
Sensory integration	Ability to organise sensory information for use (definition in Section 1.3.4)This is a collective term for a number of abilities
Balance	Ability to establish and maintain equilibrium
Bilateral integration	Ability of the two sides of the body to move together in an integrated pattern
Eye movement	Visual detection, tracking and interpretation of moving objects
Fine motor abilities	Includes grasping, hand use, eye-hand co-ordination and manual dexterity
Body awareness	Awareness of body parts by name and location, their relationship to each other and their capabilities
Motor planning	Planning of voluntary body and/or limb movement
Visual motor integration	Integration of specific areas of visual-motor behaviour with emphasis on visual perception and motor co-ordination during pencil reproduction of geometric forms
Visual motor co-ordination	Co-ordinate visual abilities with movements of the body,
Spatial perception	Ability to recognise an object's orientation or position in three-dimensional space
Figure-ground perception	Ability to select an object from a rival background
Visual closure	Ability to visualise a whole picture when only a part is visible
Form constancy	Constancy of perception of size, shape and colour even though the retinal image changes
Higher cognitive processes	Processing of cognitive processes, including selective attention, memory and problem solving skills
Emotion	Refers to emotional stability

Appendix B gives a list of assessment tools used by communication pathologists and occupational therapists. Appendix C contains the spreadsheet used in data collection.

3.6 PROCEDURES

Procedural sequence is outlined in *Figure 3.1.* The study consists of a pilot study as well as the main study.

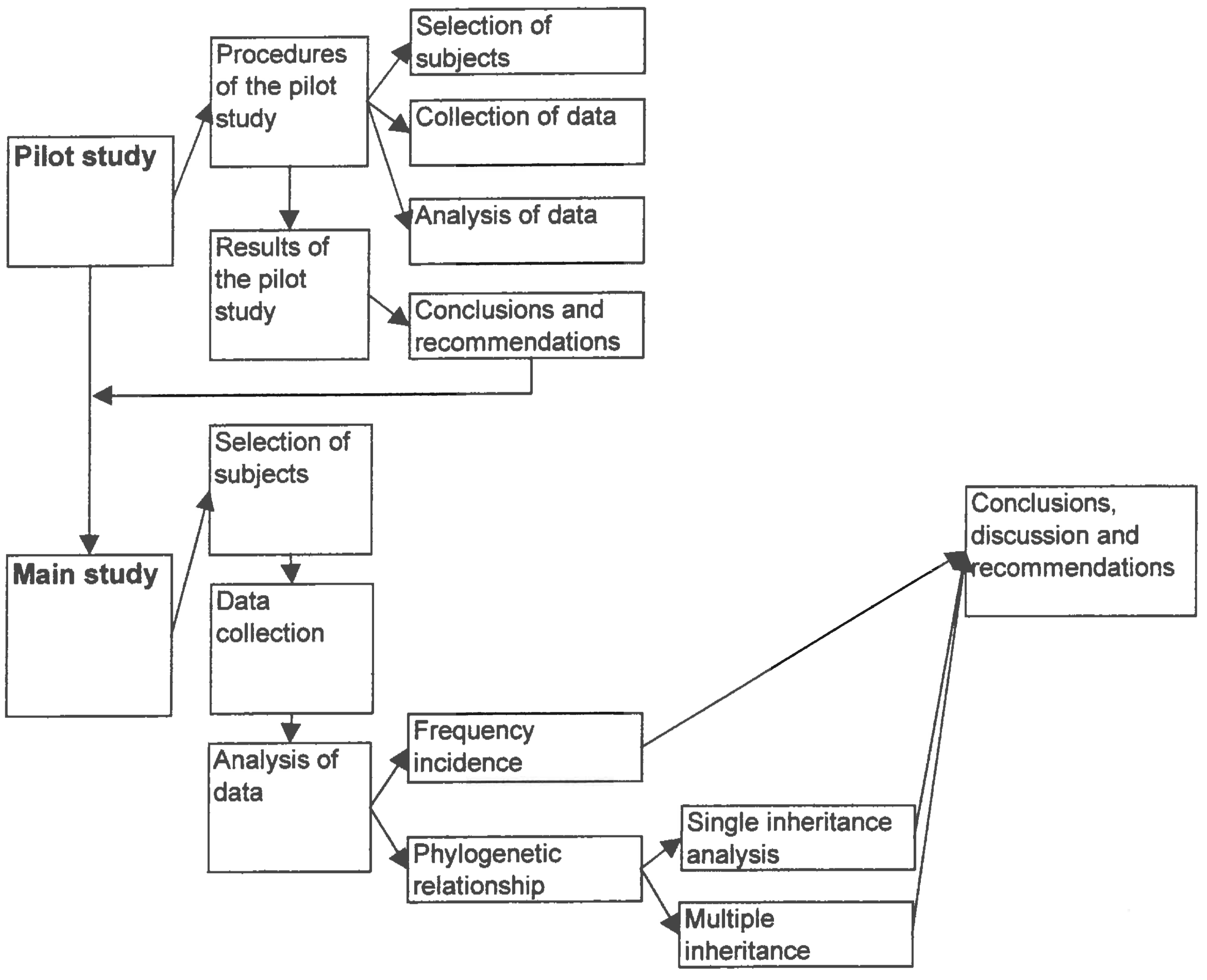


Figure 3.1: Procedural sequence

3.6.1 Pilot study

The aim of the pilot study was to assess the possibility of determining patterns of correlation by means of the analysis of existing assessment results. The pilot study was performed on data from the files of children with communication disabilities and who attended a specific nursery school attached to the Department of Communication Pathology of Pretoria University. The assessment results used in the pilot study were selected on the frequency of occurrence of problems. The same procedure was used in the final study and is more fully described in section 3.6.2.

3.6.1.1 Description of pilot study subjects

The twenty-nine children used in the pilot study were twenty boys and nine girls between the ages of three years four months and six years ten months. They all presented with communication disorders. Eight of the children were hearing impaired, of whom four had cochlear implants. Four of the children were diagnosed with Down's syndrome.

3.6.1.2 Procedures of the pilot study

The same procedures for selecting subjects and problem areas, as outlined for the main study, were followed (see section 3.4.2 and 3.5 respectively). The sample, however, consisted of a more heterogeneous group, containing children with hearing disabilities as well as children with Down's Syndrome. The twenty problem areas investigated were expressive language, auditory closure, auditory association, sound blending, receptive language, motor problems, viso-motor speed, visual closure, visual-motor integration, auditory sequential memory, eye-hand co-ordination, position in space, visual copying, visual perception, visual figure-ground perception, motor-diminished perception, spatial relations, auditory attention, auditory discrimination and form concept.

The data was manually analysed through heuristic grouping techniques in the Microsoft Excel spreadsheet application program. This computer program lends itself to easy manipulation of data and the subjects and problem areas could be visually manipulated to group problem areas together.

3.6.1.3 Results of the pilot study

The assessment results were organised and then interpreted to establish patterns of incidence of problems. These results are presented in *Table 3.4*.

The problem areas in the field of the speech- language pathologist and the occupational therapist were visually distinguished from each other in *Table 3.4,* by using different colours: yellow for the field of the speech- language pathologist and turquoise for the occupational therapist. The presence or absence ("1" or "0" respectively) was also highlighted by using colours.

Table 3.4: Results of the pilot study

							Problem areas																				
	Subject	Age	Down syndrome	Only language delay	Cochlear implant	Hearing impaired	Expressive language	Auditory closure	Auditory association	Sound blending	Receptive language	Motor problems	Viso-motor speed	Visual closure	Visual-motor integration	Auditory sequential memory	Eye-hand co-ordination	Position in space	Visual copying	Visual perception	Visual figure-ground perception	Motor-diminished perception	Spatial relations	Auditory attention	Auditory discrimination	Form concept	**Number of problems per child**
Group A	A	5.11	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**18**
	B	6.8	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**18**
	C	6.4	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	**17**
	D	4.1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	**17**
	E	5,10	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	**17**
	F	5	0	1	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	**17**
	G	5	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	**17**
	H	5.1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	**17**
	I	6,10	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	**17**
	J	4.9	0	1	1	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	**15**
	K	5.7	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	**16**
	L	5.9	0	1	0	0	1	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	0	1	**16**
	M	3,9	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	**15**
	N	4.3	0	1	0	0	1	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	1	0	**14**
	Sub total		4	9	1	1	14	13	12	13	12	10	14	13	14	12	13	14	14	14	14	14	14	11	8	6	231
Group B	O	3.11	0	1	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	0	0	**15**
	P	4,7	0	1	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	**12**
	Q	6,1	0	1	0	0	1	1	0	0	0	1	1	1	1	0	1	1	0	1	0	1	0	0	0	0	**9**
	R	4,9	0	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	**12**
	S	4	0	1	0	0	1	1	1	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0	1	**9**
	T	3,7	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	0	0	**14**
	U	4,2	0	1	0	0	1	1	1	0	1	0	1	1	1	1	0	0	1	0	1	0	0	0	0	0	**9**
	V	4.1	0	1	0	0	1	1	1	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	**6**
	Sub total		0	8	2	0	8	8	6	3	3	6	6	7	8	6	6	5	6	5	3	4	1	1	0	1	86
Group C	W	4.2	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	1	0	1	0	**13**
	X	4.4	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0	1	1	**11**
	Y	3.1	0	0	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	**8**
	Z	5	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	**7**
	AA	3,8	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**6**
	BB	3.9	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**
	CC	3,4	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**
	Sub total		0	0	2	7	7	7	7	7	6	2	3	2	1	3	1	0	1	0	1	0	1	3	3	1	55
	Total		**4**	**17**	**5**	**8**	**29**	**28**	**25**	**23**	**21**	**18**	**23**	**22**	**23**	**21**	**20**	**19**	**21**	**19**	**18**	**18**	**16**	**15**	**11**	**8**	**372**

Three categories emerged from *Table 3.4.*

- **Group A**: The first group contains children with numerous problems in the auditory, visual and language domains. This group includes the children with Down's syndrome. *These are the children with deficits not only in perceptual modalities, but also in attention, memory, cognitive and motor skills (supra-modal deficit).*
- **Group B**: The next group contains children with communication disabilities but with fewer problems especially in relation to the visual modality. These children, however, still have a great number of problems in both auditory and visual modalities. Of interest is that patterns occurred, where a number of children had the same pattern of disabilities, that is, a substantial group of children who, in addition to their disabilities in the language domain, also have visual-motor disabilities. *These children can be described as children with a mixed pattern of deficits.*
- **Group C**: The last group is a group of children with hearing disabilities with few problems involving the visual modality. These children have fewer problems overall and it can be postulated that in this last group of children the problems which emerge are rooted in the fact that they were deprived of auditory input. It is however noticeable that several of these hearing impaired children also have a substantial involvement of the visual and motor domains. Three of the children with hearing disabilities can be described as *children with a specific perceptual problem in only the auditory modality.*

These categories support the categories used by McFarland and Cacace (1995)(discussed in section 2.5.1). The results indicate that the procedure which was followed is useful to determine patterns occurring in the problem areas.

Figure 3.2 is a graphical representation of the results of the pilot study

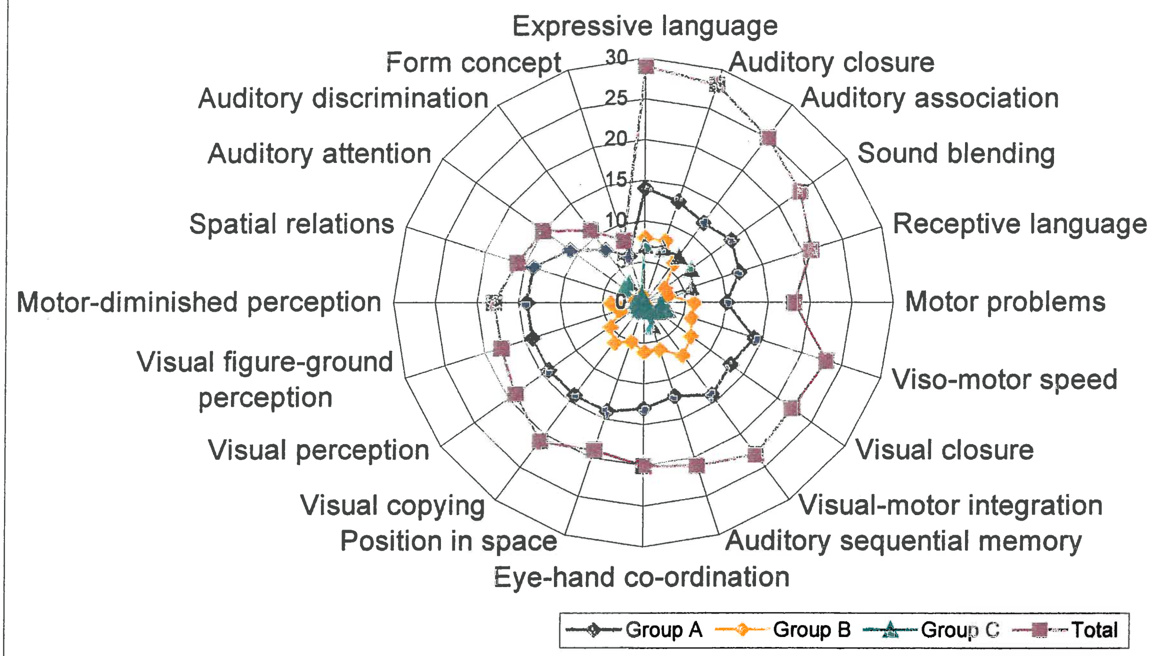


Figure 3.2: Number of problems per subject for the pilot study

The results used to compile *Figure 3.2* are the total number of problems present in a particular group as outlined in *Table 3.4*. In *Figure 3.2* it can be seen that the three groups distinguish themselves from each other by the number and nature of problems present. Group A is the group of children with a large number of problems, whereas the children in group C are children with few problems, especially in the modalities other than the auditory modality. It can thus be assumed that the choice of problem areas was meaningful and can be used as a basis for main study.

From the results of the pilot study it became clear that patterns might be detected in the correlation of problems experienced by the subjects. The procedures of data collection seemed satisfactory and the same procedures could thus be used in the main study. The following factors, however, cause the pilot study to be unsatisfactory.

- The subjects of the pilot study are from a heterogeneous group and this could have influenced the interpretation of the results. In order to achieve the research aim it was necessary to limit the subject group to children with learning disabilities. This could provide results aimed at a specific application field. The fact that children with learning disabilities are associated with central auditory processing disorders, language disorders and sensory integration dysfunction (list of references in Appendix A) and are potentially subjects to endorse the holistic approach, led to the decision to limit the subject of the main study to children with learning disabilities.
- The method used to manually manipulate the data to determine sub-groups is subjective and may thus present with different groupings if repeated. It was therefore decided to include phylogenetic analysis to scrutinise these patterns and to obtain further groups of correlation other than incidence frequency. A phylogenetic analysis provides a phylogenetic inheritance tree, which refers to relationships among broad groups. Phylogeny also provides scientifically accepted data and conclusions to show processes of natural relationships (Pagel and Harvey, 1988; Hillis, et al., 1992; Felsenstein, 1993; Pagel 1999). Phylogeny is therefore an accepted scientific method that can be repeated and produce the same results. It is also suggested in the literature that phylogenetic analysis be combined with conventional statistics to provide an accurate and descriptive tool to determine correlation (Pagel, 1999).

3.6.2 Main study

The following procedures were developed to collect the data:

- the principal of a school for remedial teaching was approached to obtain permission to use the school's filing system to collect data,
- nineteen files were randomly selected as described in section 3.4.2,
- using the problem areas indicated in the pilot study as a reference, the problem areas used for the main study were selected (as discussed in *Table 3.3*). This was done by documenting the problems areas found by the assessment team using all the relevant information in the school files on the spreadsheet mentioned in section 3.5. Material used in the data collection, consisted of biographical data, the assessments done upon admission of the subjects to the school and the assessments done most recently prior to the study. Because the dates of admission assessments spanned a number of years the format of the reports differed. The progress reports in the files gave information about the nature of the problem, but did not always give exact scores. It was also not always possible to determine from the information in the files which assessment tools were used in the assessment. The fact that the reports in the school files differed in method of diagnosis and presentation did not however pose a problem, because the issue was to determine whether a problem existed or not. The method of using a "1" for problems present and a "0" for problems absent was employed when entering the data in the spreadsheet. Phylogenetic analysis is based upon the presence ("1') or absence ("0") of an attribute of the subjects being analysed, and thus lends itself to the type of data available,

- problem areas selected were language reception, auditory closure, verbal expression, auditory analysis, fine motor abilities, auditory memory, eye-hand co-ordination, concentration, figure-ground perception, visual motor integration, visual closure, body awareness, visual analysis and synthesis, form constancy, auditory discrimination, auditory sequencing, spatial perception, auditory blending, coping emotionally, motor planning, balance, bilateral integration, eye movement and tactile defensive reactions. These problem areas are commonly found in children with learning disabilities (Clark and Allen, 1985; Keller, 1992; Koay, 1992; Katz and Wilde, 1994; Cacace and MacFarland, 1998). The choice of aspects included in the analyses was also affected by the availability of the information in the school files. Not all the aspects on the original spreadsheet used to collect the data were included in the study, because not all the information needed was available in the school files for all the subjects,
- two sets of data were selected and recorded, namely, the results of the assessment on admission to the school and the most recent assessment results prior to the conduct of this study. This was done to obtain data, which could provide information regarding the progress of the subjects in the school programme. This information is necessary to determine the relationships of the results with the knowledge of neuro-physiologic development of modalities related to learning and with this information establish the possible cause of the developmental lag if this is present.
- This information was entered into a computer using the Microsoft Excel spreadsheet program. The assessment results were encoded in a binary format namely; "0" for no problem, "1" for a problem present (discussed in section 3.5).

3.6.3 Data analysis procedures

The data was analysed using two comparative methods of determining relationships, namely, conventional frequency incidence correlation statistics and a phylogenetic relationship analysis. To use phylogeny in combination with a statistical description provides a means to determine the most probable characteristics of sub-groups for investigation (Pagel, 1999). The two sets of data, namely, those obtained from the admission evaluation and those of the most recent evaluation prior to the study were analysed using the same procedures.

3.6.3.1 Frequency incidence correlation technique

In the light of the aim of the study, the frequency incidence and distribution of the different problem areas was of interest.

To determine frequency incidence, the descriptive multiple correlation analysis technique was used In order to present the data graphically in tables and in numerical summaries. Correlations are statistical descriptions that describe the strength of the relationship between the variables (Leedy, 1993). This method indicates the progress of the subjects in the school programme by comparing the results obtained from the two sets of data. This method was chosen as it provides a systematic objective summary of the results showing the relationship between factors of interest to the study.

The analysis of the data to obtain groupings was done manually, through heuristic grouping techniques in the Microsoft Excel computer spreadsheet application program. This computer program lends itself to easy manipulation of data and the subjects and problem areas could be visually manipulated to group problem areas together. The size of the groups was determined by multiplying the total number of subjects by the total number of problem occurrences within each group. This is the same technique as that which was used in the pilot study.

3.6.3.2 Phylogenetic relationship analysis

The aim of the study, namely, to determine the nature of the relationship between central auditory processing disorders, language disorders, learning disabilities and sensory integration dysfunction was further pursued by determining the relationships existing between problem areas through phylogenetic analyses.

Phylogeny is the history of the evolution of a species referring to relationships among broad groups of organisms. Phylogeny can also refer to the history or course of development of something, for example a word. Data and conclusions of phylogeny show processes of natural relationships. Phylogeny is commonly used in the fields of palaeontology and the biological sciences. A phylogenetic tree, (a diagram showing the interrelations of a group derived from a common ancestor) provides a convenient method for the study of phylogenetic relationships (Pagel and Harvey, 1988, Felsenstein, 1993; Pagel 1999). The nature of a phylogenetic analysis is such that a reliable conclusion can be made on a small sample of specimens. Each child in this study can thus be seen as representing a species with a number of distinctive characteristics (in this case the problems areas).

The phylogenetic analysis was done by using a phylogeny inference package (PHYLIP) of computer programs (Felsenstein, 1993). These programs are intended for the use of researchers who are dealing with discrete characters or presence-absence data on restricted sites (Felsenstein, 1993). They can therefore be adapted to the individual children (species) and their abilities or disabilities (two-state characters). The following steps were followed:

- the data set as input to the phylogenetic analysis was compiled as a set of characters (ability = 0, problem = 1),
- the parsimonious trees were extracted using the DOLLOP algorithm. This program computes parsimonious trees when Dollo and polymorphism parsimony criteria are used for discrete character data with two stages (0 and 1) (Felsenstein, 1993),
- the consensus trees were extracted using the CONSENSE algorithm. This program computes majority-rule and strict consensus trees. The consensus tree consists of monophyletic groups that occur as often as possible in the data. The majority rule consensus tree consists of all groups that occur more than fifty percent of the time (Felsenstein, 1993),
- for each branch of the consensus tree, the characters common to this branch were extracted,
- each branch was analysed to form classes and sub-classes with a specific set of shared characters in each class. Each individual child forms an instance of the specific class hierarchy applicable to that child. Each child as an instance inherits (to be understood as grouping together) all the characters from the classes in the class hierarchy above this instance. As example refer to the class hierarchy shown in *Figure 3.3.* The class hierarchy contains five classes, namely; A, B, C, D and E. Instance 2 inherits characters a and b from class A, and characters e and f from class C,

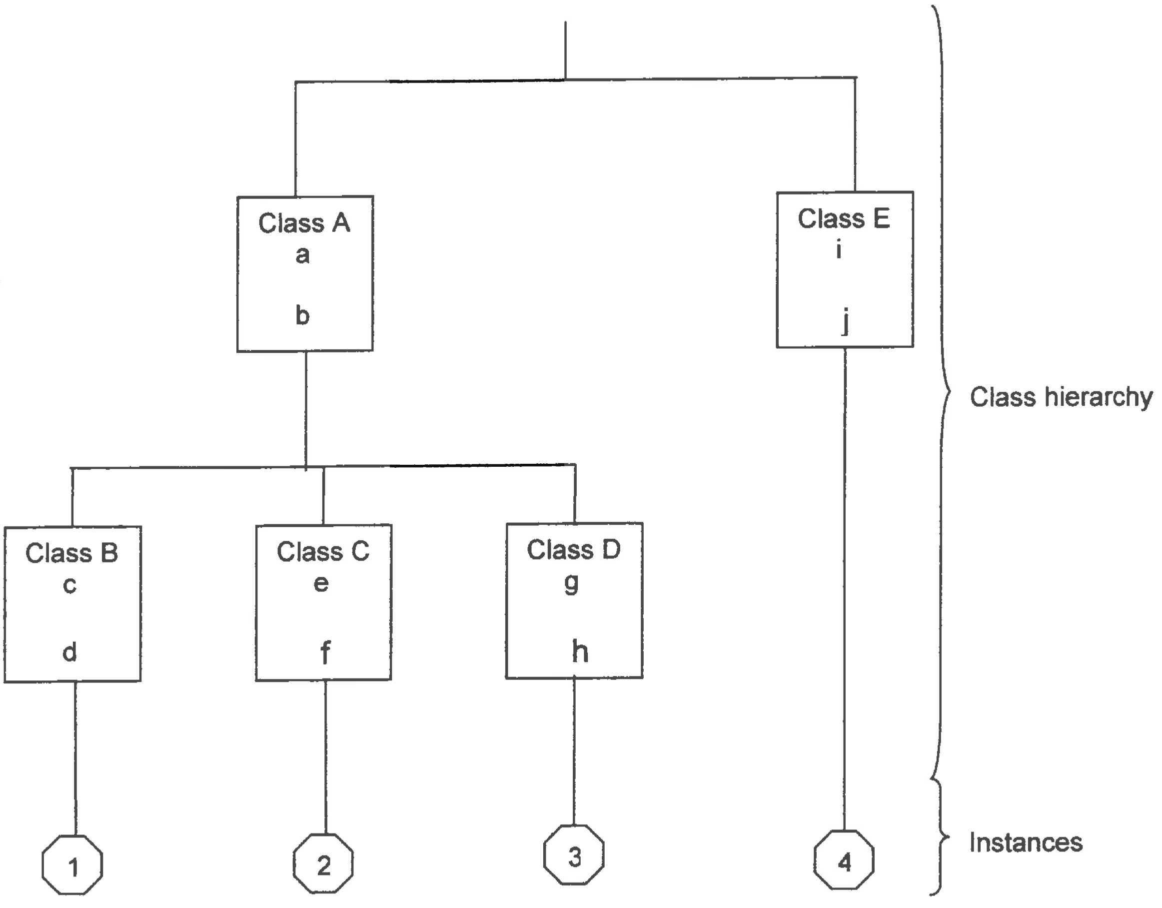


Figure 3.3: An example of a class hierarchy

- this phylogenetic analysis provides a single inheritance analysis. The results of the phylogenetic analysis are then manually analysed to determine the most parsimonious multiple inheritance tree. An example of a multiple inheritance tree is shown in *Figure 3.4*. It can be seen that individual 1 inherits a and b as well as c and d, whereas individual 2 inherits c, d, e and f.

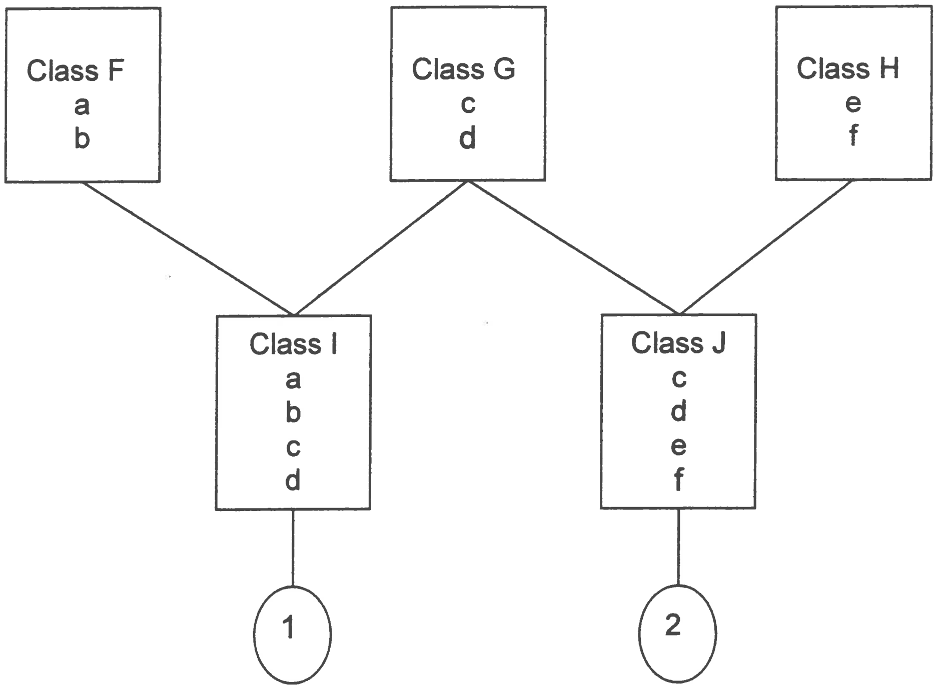


Figure 3.4: Example of a multiple inheritance tree.

The data is described in detail in chapter 4 and is presented according to the analysis methods described in this section.

3.7 SUMMARY

In this chapter, the research methodology to determine the nature of the relationship between central auditory processing, learning disabilities, language disorders and sensory integration dysfunction is described. This discussion involves the aims of the research project and the research design. The nature of the research subjects and the assessment data used in the analysis are also described. The procedures followed and the results of the pilot study are explained. The occurrence of categories of children with certain patterns of problems, is an important finding of the pilot study and this motivated the procedures of the main study. The data analysis methods, namely, the conventional descriptive multiple correlation analysis technique and the phylogenetic analysis are described. An in-depth discussion of the data and the analysis of the data will be included in chapter 4.