Relationship Patterns Between Central Auditory Processing Disorders and Language Disorders, Learning Disabilities, and Sensory Integration Dysfunction

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Central auditory processing disorders often present with language disorders, sensory integration dysfunction, and learning disabilities (LD). In this study, a multimodal assessment of children with LD was used to identify certain problem areas. Phylogenetic analyses established the nature of the relationship among these areas and grouped them according to shared problem areas. The majority of children presented with deficits involving both the visual and auditory modalities, as well as problems with motor abilities and concentration skills. Within this majority group, further subgroups of problem areas were found to occur together. The results suggest that a multimodal perceptual approach is useful for enhancing diagnosis of and choosing interventions for these children.

Problems related to central auditory processing disorders (CAPD) often present with problems related to language disorders, sensory integration dysfunction, and learning disabilities (LD). This phenomenon is accepted by most researchers in these areas (American Speech-Language-Hearing Association [ASHA], 1996; Ayres & Mailloux, 1981; Bellis & Ferre, 1999; Cacace & McFarland, 1998; Chermak, 1998; Chermak, Hall, & Musiek, 1999; Gordon & Ward, 1995; Katz & Wilde, 1994; Keith, 1984; Keith & Stromberg, 1985; McSporran, 1997; Sloan, 1998; Tallal et al., 1996; Welsh, Welsh, & Healy, 1996). In working with children with these problems, teamwork is essential (Chermak, 1998; Koay, 1992; Sanger, Freed, & Decker, 1985; Young, 1985; Young & Protti-Patterson, 1984), and a collaborative and integrated multiprofessional approach is needed because different kinds of professionals tend to look at these disorders from different perspectives. The present approach to the clinical diagnosis of and intervention for the co-occurrence of CAPD, language disorders, LD, and sensory integration dysfunction might be viewed as a fragmented one in which every professional involved functions in isolation. There thus is a need for a fundamental model that can integrate approaches and schools of thought in diagnosis and intervention with respect to children with these problems.

Currently, the most favored approach in South Africa is an interdisciplinary one. Unfortunately, it requires more funds and skilled human resources than are presently available in the South African educational community. As a result, a large proportion of this population is not receiving proper management of the problem. An effective, resource-efficient, transdisciplinary model for helping children with CAPD, language disorders, LD, and sensory integration dysfunction will aid in providing an evaluation and intervention program that may be easily implemented using existing resources.

To clarify the need for a holistic view of and approach to CAPD, language disorders, LD, and sensory integration dysfunction, it is necessary to look at the intersensory nature of learning development (Bellis & Ferre, 1999; Cacace & McFarland, 1998; Lewkowicz & Lickliter, 1994; Welsh et al., 1996). Multimodal perceptual testing and the holistic integration of assessment results will enhance the integration of diagnosis and intervention in this area. This study proposes a method for establishing such a holistic approach to multimodal testing and diagnosis.

The rationale for this study is rooted in the need for a more cost-effective and efficient, child-centered intervention strategy for children experiencing the group of disorders under consideration. One of the ways in which to approach the problem is to ascertain whether or not the conventional assessments currently used in schools for children with LD can also be employed in such a way as to assist in the holistic management of these children, incorporating and even promoting the transdisciplinary team approach. The objective of this study is to analyze overlapping patterns in the occurrence of problems identified during diagnostic assessment of a group of children in a school for remedial education in order to elucidate the *nature* of the interrelationship of the group of pathologies falling under the umbrella of Developmental Learning Disorders, according to the *DSM-IV* (American Psychiatric Association, 1994).

Analyzing overlapping patterns of problems requires a methodology to extract groupings from a set of instances (individual children, in this case) and each instance with its own set of traits (problems, in this case). The size of these groupings (number of children in a group) should be based upon the maximum sharing of common traits. Determining objectively (a) the frequency of occurrence of combinations of problems and (b) the frequency of occurrence of individual problems is necessary. This study proposes that using a phylogenetic analysis approach with individual children in the sample group as instances, each with a set of problems, will do this.

Our theory was that in a sample randomly selected from a population of children with LD, there would be groups of children concurrently experiencing problems traditionally managed by professionals in the fields of communication pathology, occupational therapy, and psychology. If this theory was correct, the objectively derived significant groupings should contain problems currently classified as belonging to more than one of the above-mentioned fields. If this proposition was not correct, these groupings should each contain only problems currently classified as belonging to a single one of the above-mentioned fields.

METHOD

Participants

The participants consisted of a group of children attending a school for remedial education of children with LD but with otherwise normal cognitive abilities. Candidates for this study were required to belong to the group of children with developmental learning disorders, which included CAPD, language disorders, LD, and sensory integration dysfunction. CAPD, as viewed in this study, can be defined as disorders in the information processing of acoustic signals not due to impaired hearing sensitivity or intellectual impairment (ASHA, 1996). The definition of the term *language* used by Owens (1995)—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—applies in this study. The extensive definition of LD proposed by ASHA's position statement on LD (in Owens, 1984, p. 331) was used: "Learning disability is a general term that refers to a diverse group of developmental and educational disorders. These disorders are realized as significant difficulties in the acquisition and development of listening, speaking, reading, writing, and mathematical abilities." In the study, the meaning of the term *sensory integration* was the same as that used by occupational therapists: Sensory integration is the organization of sensation for use, a primary function of the central nervous system. Sensory integration is processing of information (Ayres, 1983; Fisher & Murray, 1991). Through integration, a "whole" is revised or produced from fragmented parts (Ayres, 1983).

The participants were 19 children, 5 girls and 14 boys between the ages of 4 years 4 months and 9 years 7 months. This group of children was randomly selected from 150 children attending the school. A criterion for inclusion was *adequate competence in English,* primarily because standardized tests for central auditory processing abilities are readily available in English. At the school used in the investigation, teaching and therapy are conducted in English. The children receive remedial education, speech and language therapy, occupational therapy, and specific remedial teaching. Although the school expects competence in English, 5 of the children were non-native English speakers (1 child's native language was Italian; the other 4 spoke Afrikaans). This is typical of South Africa; therefore, research should 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).

Normal peripheral hearing was also a criterion for inclusion because this is a prerequisite for the diagnosis of CAPD (ASHA, 1996; Cacace & McFarland, 1998; Jerger, Martin, & Jerger, 1987; Keith, 1984; McFarland & Cacace, 1995). High-risk factors were present for 16 children:

- Williams' syndrome (1)
- history of hemolytic streptococcal septicemia (1)
- premature birth (3)
- history of otitis media (11)

The number of participants met the criteria for a phylogenetic analysis method (Felsenstein, 1993; Hillis, Bull, White, Badgett, & Moloneux, 1992; Pagel 1999; Pagel & Harvey, 1988). Initially, the intention had been to include a larger sample (all the pupils attending the school), but after a trial analysis with 10 children to become conversant with phylogenetic analysis, it became clear that a large group was not required. We do not believe that significant additional groupings would have been found if more participants had been included, because the core of the patterns was already evident. This fact became clear when the data analysis for the 10 participants in the trial was compared with the data analysis for the 19 participants. Random selection using the simple convenience sampling method was used (Leedy, 1993).

Data Collection

The assessment results of the professional team (communication pathologists, occupational therapists, remedial teachers, and a psychologist) involved with the initial assessment were the data of interest to this investigation. Problem areas were selected by reviewing the documentation of the problem areas found by the assessment team, using all the relevant information in the school files. Material used in the data collection thus consisted of both biographical data and formal test materials, as outlined in Table 1. These were administered upon admission of the children to the school. Only nonaudiological tests were administered to determine CAPD, because standardized South African CAPD audiological test materials are currently not available. A South African CAPD taskforce has been formed to address this shortcoming (Campbell & Wilson, 2000). The dates of admission assessments spanned a number of years; therefore, the format of the reports differed. 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. The formal test results and normative data provided by these tests were used to determine the presence of a problem. The method of using a "1" for problems present and a "0" for problems absent was employed when entering the

TABLE 1. Battery of Tests and Assessment Procedures Used by the Professional Team

Test	Description	Developed by
	Tests used by the communication pathologist	
Test of Auditory Perceptual Skills–Revised	Identifies auditory perceptual difficulties and language/learning problems	Gardner (1996)
Peabody Picture Vocabulary Test–Revised	Measures vocabulary comprehension	Dunn & Dunn (1981)
Illinois Test of Psycholinguistic Abilities	Assesses aspects of language processing and central auditory processing	Kirk, McCarthy, & Kirk (1968)
Auditory Memory Span Test	Assesses auditory memory	Wepman & Morency (1973)
Test of Auditory Analysis Skills	Assesses auditory analysis abilities	Rosner (1975)
Reynell Developmental Language Scale–Revised	Measures language reception and expression	Reynell & Huntley (1987)
Clinical Evaluation of Language Functions–Revised	Measures language skills	Semel, Secord, & Wiig (1987)
Test of Language Competence	Measures specific language abilities	Wiig & Secord (1985)
	Tests used by the occupational therapist	
Development Test of Visual Perception	Measures visual perception skills important to school readiness	Frostig, Lefever, & Whittlesey (1966)
Southern California Sensory Integration Tests–Revised	Clinical observations of neuropsychological patterns of disorder	Ayres (1980)
Test of Visual–Motor Integration	Measures visual–motor integration	Beery (1989)
	Tests used by the psychologist	
Junior South African Individual Scale–Revised	Measures intellectual abilities (3 years 0 months to 7 years 11 months)	Van Eeden (1992a)
Senior South African Individual Scale–Revised	Measures intellectual abilities (7 years 0 months to 16 years 11 months)	Van Eeden (1992b)
Bender Gestalt	Assesses emotional state	Bender (1963)

data. Phylogenetic analysis is based upon the presence ("1") or absence ("0") of a trait of the participants being analyzed and thus lends itself to the type of data available.

The problem areas selected in the area of *speech–language pathology* were language reception, auditory closure, verbal expression, auditory analysis, auditory memory, auditory discrimination, auditory sequencing, and auditory blending (normal print in Figures 1 through 3). Problem areas selected in the area of *occupational therapy* were fine-motor abilities, eye–hand coordination, figure-ground perception, visual motor integration, visual closure, body awareness, visual analysis and synthesis, form constancy, spatial perception, motor planning, balance, bilateral integration, eye movement, and tactile defensive reactions (bold italics in Figures 1 through 3). In the area of *psychology,* concentration and emotional coping abilities were selected (underlined in Figures 1 through 3). These problem areas are commonly found in children with LD (Cacace & McFarland, 1998; Clark & Allen, 1985; Katz & Wilde, 1994; Keller, 1992; Koay, 1992).

Data Analysis Procedures

To determine the nature of the relationship between CAPD and language disorders, LD, and sensory integration dysfunction, phylogenetic analysis was chosen as a scientific and objective method for determining the relationships existing among problem areas. *Phylogeny* is the history of the evolution of a species, in particular, as regards relationships among broad groups of organisms. Phylogeny can also refer to the history or course of development of something, for example, a word. Data from and conclusions of phylogeny show processes of natural relationships. Phylogeny is commonly used in paleontology and the biological sciences. A single inheritance 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 (Felsenstein, 1993; Pagel 1999; Pagel & Harvey, 1988). A multiple inheritance tree extends single inheritance phylogenetic trees to include phylogenetic relationships with more than one ancestor. The nature of a phylogenetic analysis is such that a reliable conclusion can be made from a small sample.

This study makes the assumption that each child may be considered to be a representative (or instance) of a species with a number of distinctive traits (in this case, the problem areas). Figure 1 contains an example that illustrates the way in which this study used a single inheritance tree. It shows this tree (with the root at the top of the figure) forming a class hierarchy with Classes A and E and Subclasses B, C, and D, each

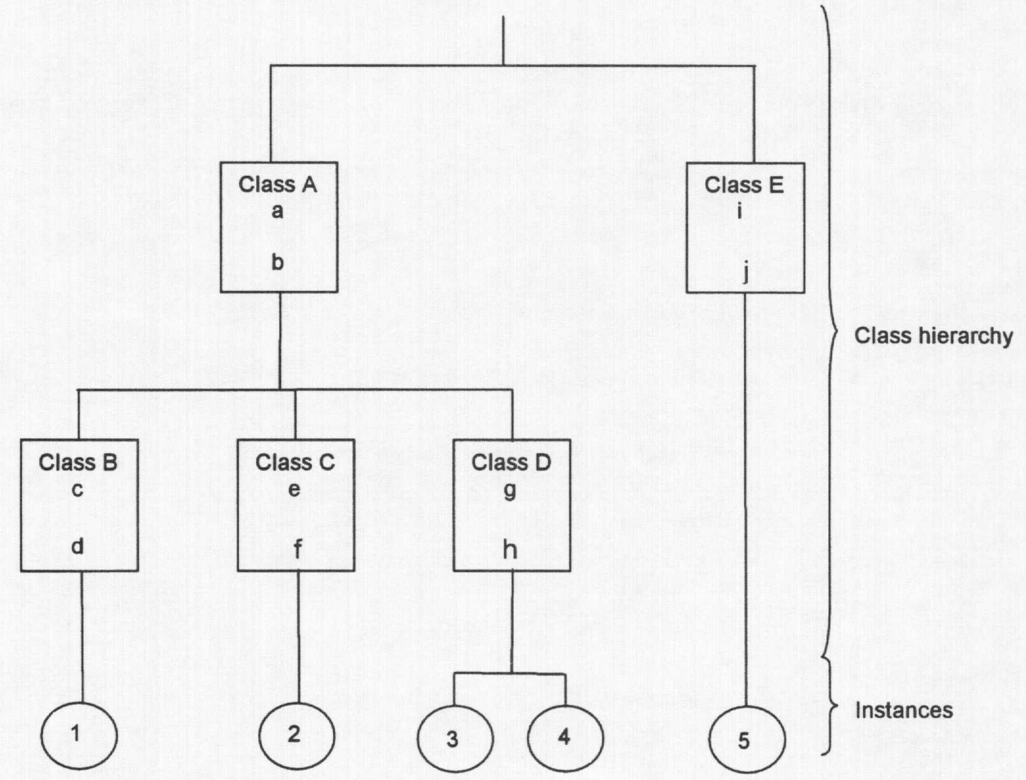

FIGURE 1. Example of a single inheritance tree with classes, subclasses, and instances with the root at the top and the branches branching downwards.

of which has a set of shared traits. 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, not in an evolutionary or biological hereditary sense) all the traits from the classes in the class hierarchy above this instance. In Figure 1, Child 2, for example, inherited Traits a and b from Class A and Traits e and f from Class C. Children 3 and 4 shared the same Traits—a, b, g, and h. The single inheritance tree provides a way to depict inheritance of traits from a single hierarchy of classes, but it lacks the ability to depict inheritance of traits from more than one unrelated class. This limitation may be overcome by using multiple inheritance trees.

An example of the use of a multiple inheritance tree is shown in Figure 2. Here, for example, in Instance 1, a member of Class I inherited Traits a and b from Class F and Traits c and d from Class G. Note that in contrast to the hierarchy convention used in the single inheritance tree, here a class is shown to contain all the traits shared by an instance of that class. (This convention is followed in order to facilitate easier reading of the shared traits in subsequent single and multiple inheritance trees, which will be presented later.)

This study derived both single and multiple inheritance trees. The single inheritance phylogenetic analysis was performed using a phylogeny inference package (PHYLIP) of computer programs (Felsenstein, 1993). Parsimonious trees were extracted using the DOLLOP algorithm, and the consensus trees were extracted using the CONSENSE algorithm, resulting in the single inheritance tree. A manual searching procedure was followed in order to generate the most parsimonious multiple inheritance tree (Krüger & Krüger, 2000).

RESULTS AND DISCUSSION

The number of occurrences of each individual problem for the sample group is shown in the "Total" column in Figure 3. The DOLLOP algorithm computer program found 48 trees. The CONSENSE algorithm computer program analysis yielded the consensus inheritance tree as shown in Figures 3 and 4. In Figure 3 the shaded blocks indicate the groupings found by the CONSENSE program on the DOLLOP analysis. In Figure 4 the groups that emerged from the consensus inheritance tree are outlined in the class hierarchy (Groups A, B, C, D, etc.). The number in the block at the bottom right-hand side of the group block indicates the number of children belonging to the particular group. For example, Child c and Child d inherited traits (problems) from the groups along the inheritance chain, which starts at the top group (of which all 19 participants are members) and runs through Groups B, E, J, M, and P. As a further example, 5 children (s, a, x, d, and c) are members of Group J. Their common problems were fine-motor skills, auditory memory, visual motor integration, visual closure, and auditory sequencing (from being members of Group J); problems with balance and eye movement (from being members of Group E), and problems with body awareness (from being members of Group B).

Analysis of the groups in the single inheritance tree of Figure 4 indicated that further problems were shared by members of more than one unrelated (adjacent) group. For example, the problems of language reception, auditory closure, and verbal expression were shared by members of Groups A, D, and H. This indicates a need for accommodating inheritance from more than one unrelated group, as supported by multiple inheritance trees.

Only significant groups (with more than 8 children) were taken into account in the outline representation of the multiple inheritance tree in Figure 5. The number of children belonging to a particular group is indicated in the small block at the bottom right-hand side of the group block. Note that, in contrast to Figure 4, the groups in Figure 5 contain all the problems shared by members of that group. The 13 members of Group AG, for example, all shared problems with language reception, auditory closure, verbal expression, auditory analysis, fine-motor skills, and eye–hand coordination. In the case of the multiple inheritance groups, an individual child might belong to more than one unrelated group. A specific child, for example, could be a member of both Groups AG and AF. Such a child would have all six of the problems listed above due to being a member of Group AG, as well as problems with motor planning, auditory discrimination, and bilateral integration due to being a member of Group AF. For the sake of conciseness, Figure 5 is a multiple inheritance class structure, which does not show how each child inherited all of the problems he or she had.

The groupings in Figure 5 were generated by implementing a manually executed systematic algorithm that searched for the largest groupings of shared problems while not restricting a group member belonging to only a single

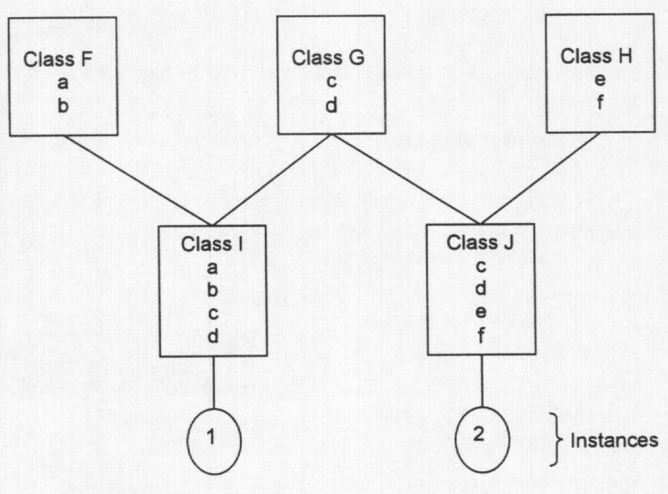

FIGURE 2. Example of a multiple inheritance tree.

Child:	h	f	l	j	m	n	r	e	o	q	k	b	g	p	s	a	x	d	c	
Problem areas																				Total
Language reception	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	18
Auditory closure	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	18
Verbal expression	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	17
Auditory analysis	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	17
Fine motor coordination	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
Auditory memory	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	16
Eye-hand coordination	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	16
<u>Concentration</u>	1	0	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	15
Figure-ground perception	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	15
Visual-motor integration	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Visual closure	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Body awareness	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	14
Visual analysis/synthesis	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	14
Form constancy	0	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0	1	14
Auditory discrimination	0	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	0	0	1	13
Auditory sequencing	0	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	14
Spatial perception	0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	13
Auditory blending	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	0	13
<u>Emotion</u>	0	1	0	0	1	1	0	1	1	0	0	1	1	1	1	1	1	1	0	12
Motor planning	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	12
Balance	0	0	0	1	1	0	1	1	1	0	0	0	1	1	1	1	1	1	1	12
Bilateral integration	0	0	0	0	1	0	1	1	1	1	0	1	1	1	1	1	1	0	0	11
Eye movement	0	0	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	1	1	9
Tactile defensive	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	0	1	9
Number of problems:	7	8	13	13	18	19	21	20	20	20	17	21	21	23	24	21	22	14	16	

FIGURE 3. Problem areas indicating number of occurrences of individual problems, data used in the phylogenetic analysis, and groups found by the single inheritance analysis.

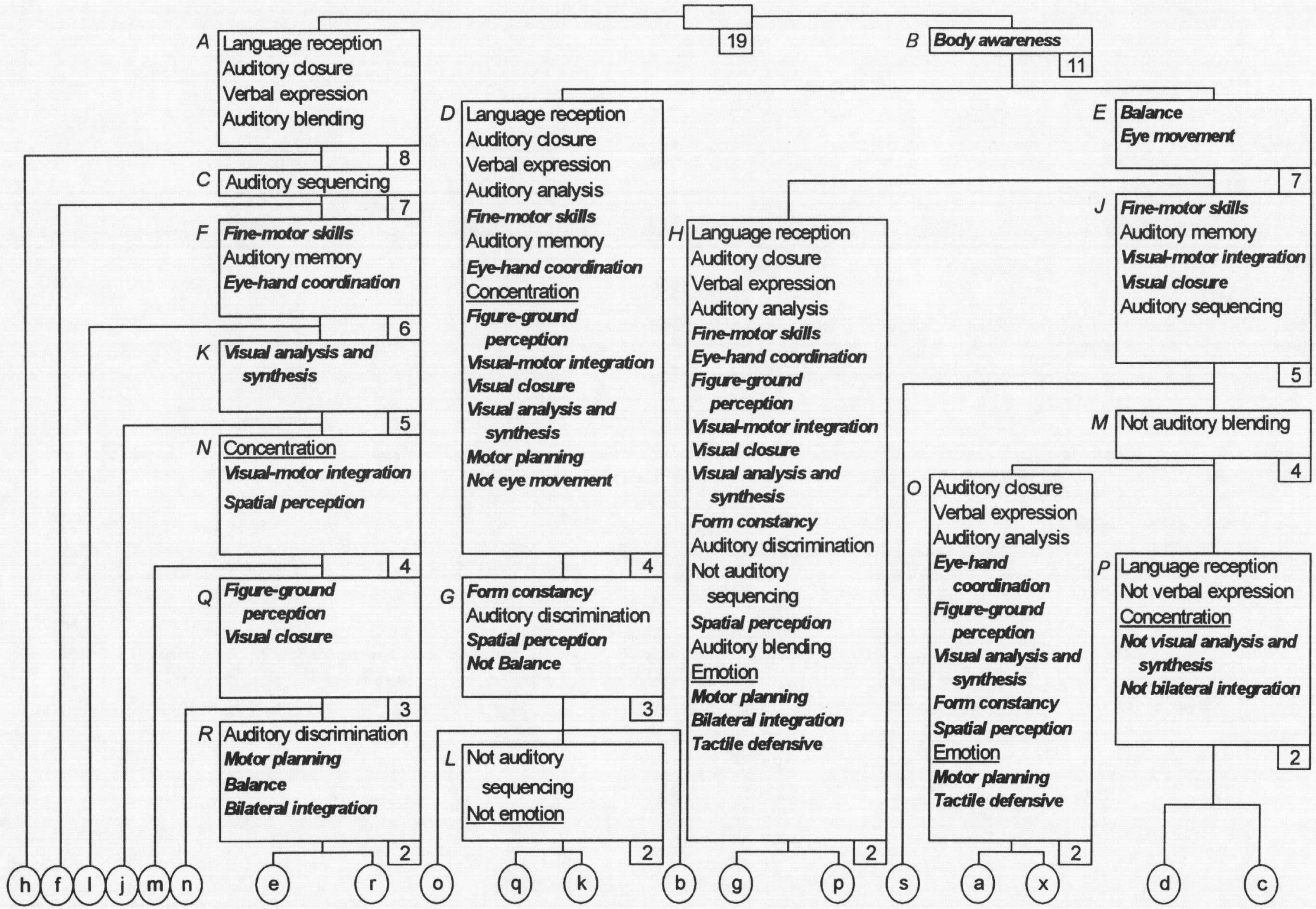

FIGURE 4. Single inheritance tree based on the results of the consensus tree obtained from the DOLLOP phylogenetic analysis.

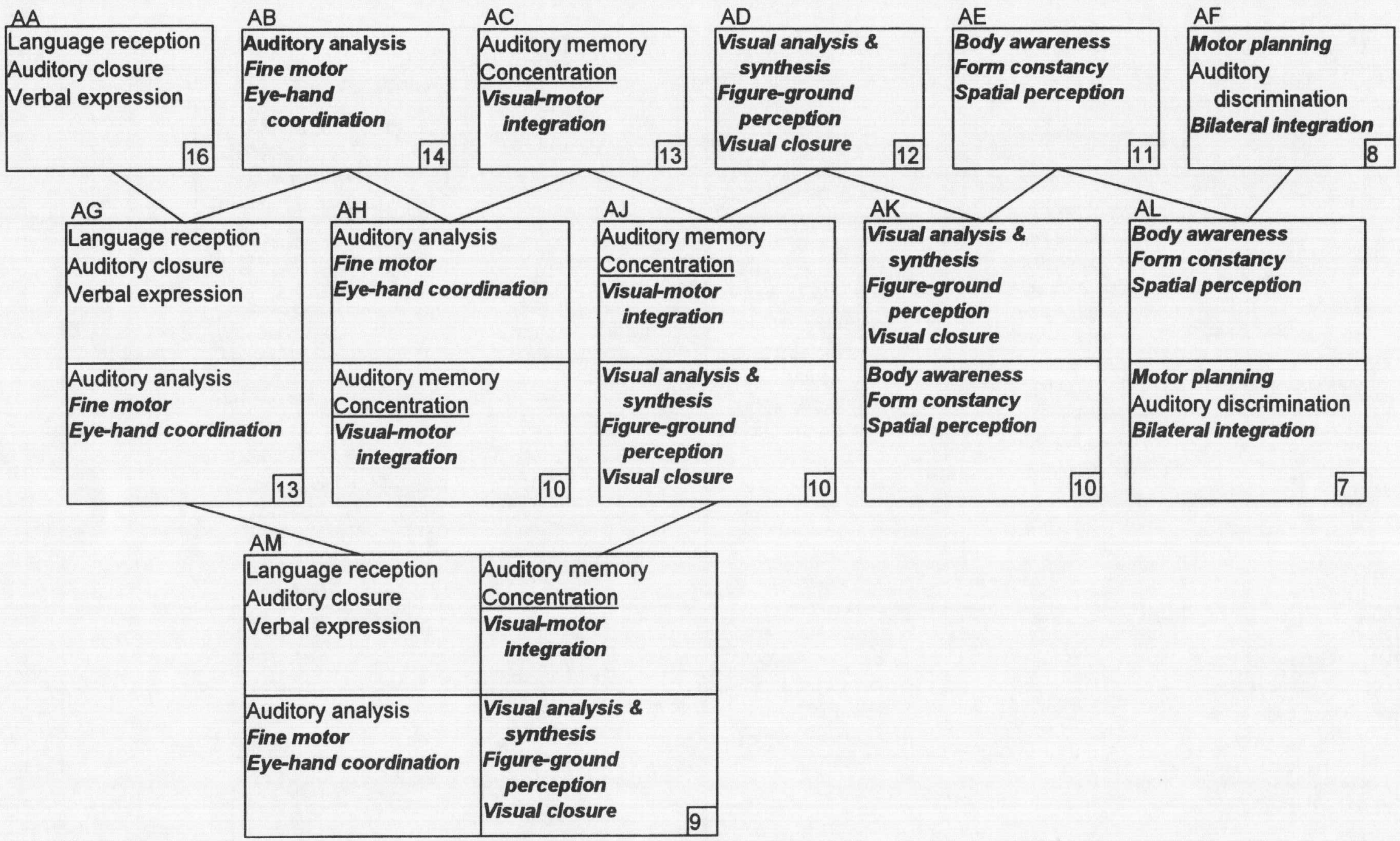

FIGURE 5. Multiple inheritance class structure.

vertical path of groups and subgroups. This resulted in the creation of the largest group—Group AA. This set of problems, incidentally, was identified as a group that could not be grouped separately in the single inheritance tree due to the single ancestry implications of the tree's technique.

Analysis of the single inheritance tree in Figure 4 identified two groups with seven members each, namely, Groups C and E. Group C contained five problems restricted to the domain of communication pathology. Group E contained three problems restricted to the area of occupational therapy. This would seem to suggest that the groupings fell into the traditional two fields mentioned. Further analysis indicated that, for example, intermodal problems with fine-motor skills, auditory memory, and eye–hand coordination grouped together within Groups F and D, which combined had 10 members. Such analyses of the groupings suggest that the single inheritance tree may suppress the identification of a disability group containing problems of auditory, visual, somatosensory, motor, and supramodal factors, all of which influence the processing of information. This observation refers to the results obtained with the multiple inheritance tree.

In the multiple inheritance class structure of Figure 5, Group AM had nine members, and contained 12 problems of a mixed nature (i.e., problems of auditory, visual, somatosensory, motor, and supramodal factors). This relatively strong group of shared problems provides support for the existence of a developmental learning disorder containing problems in the domains of communication pathology, occupational therapy, and psychology. If one looks at the problems shared by the 13 members of Group AG, this pattern still seems to be largely true.

The results from both the single and multiple inheritance analyses support the proposition that there are children who concurrently experience problems traditionally managed by professionals in the fields of communication pathology, occupational therapy, and psychology. This is shown in Figures 4 and 5 by the roman, bold italic, and underlined problems.

In both sets of results from the two analysis methods, the existence of patterns of problem areas is clear. The majority of children presented with deficits simultaneously involving both the visual and auditory modalities, as well as problems with motor abilities and concentration skills. Within this majority group, further clusters of problem areas occurred together.

Analysis of the groupings shows that the majority of children in this study had problems in all the modalities under investigation, as shown in the single inheritance tree in Figure 4, and could be classified as belonging to the group of children with supramodal deficiencies. Only two children (h and f) were grouped together as having only language problems and CAPD.

It may seem as if the results obtained by means of the inheritance tree analyses are directly evident from the data in Figure 3. Note that for illustrative purposes these data have already been grouped according to the outcome of the single inheritance grouping processes. The real raw data do not point to groupings of problems that occurred simultaneously in a large proportion of the children in this study. The fact that the patterns are evident from the representation in Figure 3 confirms that the single inheritance analysis already makes the existence of patterns evident. An advantage of the patterns established in both inheritance groupings is that these are derived in a completely objective manner, according to the set of rules implemented in the algorithms used. In addition, the sample of participants was chosen randomly from the total population of the school under consideration, thus eliminating any bias in the sample. Regarding the size of the sample, it should be noted that the analysis techniques used were designed to also work well with small numbers of specimens, mainly because no averaging techniques were used. All traits of all instances were taken into account in the total set of resultant groupings.

A feature emerging from the multiple inheritance analysis was that language and central auditory processing problems comprised the problem areas in the case of the largest number of children. Figure 5 shows that these problems occurred mostly in the groups with larger numbers of children. Noteworthy also was the high incidence of problems with advanced visual and motor skills that occurred in conjunction with problems in central auditory processing skills (e.g., Groups AB and AC in Figure 5). Examples of significant groupings included the following:

- Group AM in Figure 5 (19 children [47%]). Members of this group had problems in language processing; fine-motor coordination; concentration; memory; analysis; and synthesis for auditory, visual, and somato-sensory modalities. This group could also be seen as a "supramodal" group with an underlying concentration problem as the main cause of the problems (Cacace & McFarland, 1998).
- Group AB (14 children [74%]; see Figure 5) contained problems in fine-motor coordination of eye–hand, motor, and auditory–semantic skills.
- Group AG (13 children [68%])consisted of children with the problems found in Groups AA and AB. This group could be described as having problems in language processing and fine-motor coordination. All these skills could also be described as higher-order processing skills.
- Group AJ (10 children [53%])consisted of the problems in Groups AC and AD (Figure 5). This group could be described as having problems with concentration; memory; and analysis of and synthesis for auditory, visual, and somato-sensory modalities. Group AJ could be considered to be a supramodal group, with the possible root of the problems being the under-

lying lack of sufficient concentration (Cacace & McFarland, 1998).

The *simultaneous occurrence of a language disorder* (problems with verbal expression and language reception, combined with problems with auditory closure) *was the combined deficit with the highest incidence* (Group AA in Figure 5), although only children with LD were selected. This suggests a close link between language abilities and LD. This is significant in the sense that it can be assumed that a language disorder may possibly be at the root of a learning disability, an assumption accepted by numerous researchers (e.g., ASHA, 1996; Bernstein & Stark, 1985; Cacace & McFarland, 1998; Campbell, 1994; Cline, 1988; Gordon & Ward, 1995; Keith, 1984; Lewis, Freebairn, & Taylor, 2000; Riccio, Hynd, Cohen, Hall, & Molt, 1994; Sanger, Decker, & Freed, 1987; Sloan, 1992). In this regard, Chase (1996) suggested that the underlying neurophysiological processes in children with LD are similar to those of children with language disorders.

All the children had a deficit in their linguistic skills (Figure 3). This interpretation must, however, be made with circumspection. The fact that the assessment tools used to evaluate central auditory processing skills in this study were all linguistically based assessments could have affected the outcome of the assessment results (Perez et al., 1995). It is possible that several of *the children could have had problems in correctly interpreting the instructions* for the activities required of them during the evaluation by the occupational therapist. However, it is also possible that the deficits in the concept-forming abilities associated with relationships of the sensory systems and the outside world could have influenced the ability to follow instructions (Gabbard, 1992).

According to the single inheritance hierarchy, *only two children in this study could be described as having a pure language and central auditory processing deficit* (Children h and f in Figure 3 and Figure 4). No child could be described as having a sensory deficit in only the visual modality or even a visual–motor deficit. Analysis of the nature of the grouping of problem areas in Figure 2 and 3 indicated that a significant group of children existed in which, in addition to the presence of high-incidence problems, a greater number of problems in the visual modality occurred. These findings lead to the conclusion that language and central auditory processing skills should not be separated from skills involving the visual modality, as stated by Cacace and McFarland (1998) and Chermak et al. (1999).

The *presence of an attention deficit in a large percentage of children* could also have affected the assessment results. Out of the 19 children in the study, 15 had problems with concentration, as can be seen in Figure 3. Furthermore, the results indicated a high incidence of problems with concentration skills (see Figure 3). Fifty-three percent of children fell into the groups where concentration problems were evident, according to the single inheritance phylogenetic analysis (see Figure 4). In the multiple inheritance analysis, concentration problems were present in groups with up to 13 children (see Figure 3). Concentration problems also presented simultaneously in groups with auditory memory and figure-ground perception problems—areas requiring attention abilities (Figures 4 & 5). The ability to attend to an activity was a determining factor during the assessment of each child. This fact suggests that attention skills are also important in academic performance and for language ability, central auditory processing, and sensory integration. The question may be asked as to whether the deficit in attention influenced the assessment results due to the inability to give attention to the activities and distractions present during the assessment procedures, or whether this attention deficit influenced the development of these skills (ASHA, 1996; Cacace & McFarland, 1998; Chermak et al., 1999; Comings, 1990; Kim & Kaiser, 2000; McFarland & Cacace, 1995; Riccio et al., 1994; Stach, 1992). The aforementioned authors acknowledged a comorbidity of CAPD and attention-deficit disorder but regarded the two deficits as two distinct clinical disorders. The finding that concentration problems were not of a similar high incidence as a number of problems with auditory processing skills suggests that CAPD is not analogous to attention-deficit disorder (ASHA, 1996; Cacace & McFarland, 1998; Chermak et al., 1999; McFarland & Cacace, 1995; Riccio et al., 1994; Stach, 1992).

In addition to the high incidence of language deficits, *aspects of CAPD presented with a similar high incidence* (auditory closure and auditory analysis in Figure 3). This could be due to the overlapping nature of central auditory processing and language processing, an assumption that has been acknowledged (Bellis & Ferre, 1999; Chermak, 1998; Katz & Wilde, 1994; Keith, 1984; McSporran, 1997; Sanger, Keith, & Maher, 1987; Sloan, 1998). The idea that CAPD could be the underlying cause of many language disorders has been proposed by a number of authors employing neurophysiologic (Cacace & McFarland, 1998; Chase, 1996) and behavioral evidence (Cacace & McFarland, 1998; Fitch, Miller, & Tallal, 1997; Tallal et al., 1996).

It is important to note that although children were categorized into groups, careful further analysis of the results underlined the heterogeneity of the entire sample. Every single child should therefore still be treated as an individual within any larger group.

CONCLUSIONS

From the analysis of the data obtained by using phylogenetic inheritance analysis, it was evident that no deficit in the sample of children with LD was isolated from any other deficit. Significant groupings were apparent, indicating that the children all presented with deficits in more than one modality or skill. Language seemed to be the primary deficit area; therefore, an assumption can be made that an interrelationship among auditory, visual, somato-sensory, motor, and language skills should be acknowledged. Although language disorders and LD were present for all the children, no child had a pure language disorder or only academic learning problems without any involvement of sensory systems—auditory, visual, somato-sensory, or all three.

Most inheritance groupings obtained from the single and multiple inheritance class hierarchy analysis consisted of problem areas grouped in a mixed manner from auditory, visual, and somato-sensory systems. Motor skill problems and supramodal problems also played a role in a number of problem areas under investigation and also occurred with sensory perceptual and processing deficits. From the results, it is thus clear that neurophysiological integration of the sensory and motor systems weighs heavily in the development of academic skills.

The fact that professionals from various specialized fields view disorders from individual perspectives hampers the effective management of children with CAPD, language disorders, LD, and sensory integration dysfunction. Professionals operating under this orientation provide isolated and inefficient treatment for these children. We propose changing to a holistic team approach.

The interrelationships among academic, central auditory processing, language processing, and sensory integration abilities are clearly illustrated in this study. Therefore, it can be inferred that children with CAPD, language disorders, LD, and sensory integration dysfunction cannot be viewed and treated in an isolated manner but should be seen as exhibiting signs and symptoms under an umbrella syndrome condition, one that can be described as a developmental learning disorder as advocated in *DSM-IV*. These children present with a number of problem areas (signs and symptoms) that are commonly found in all of these disabilities.

This study proposes a multimodal approach for both diagnosis and intervention. Analysis of the results suggests that a holistic diagnosis and intervention approach—that is, a strong interdisciplinary or transdisciplinary team approach—is one way to effectively deal with the problems these children present. A collaborative, professional team approach is indicated to establish the patterns of the disorders at the multimodal level. In South Africa, the challenge is providing adequate professional services by only a few professionals to a large population. An effective resource-efficient model for the management of these children will aid in providing an evaluation and intervention program that may be easily implemented with existing resources.

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