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THE UNIVERSITY OF ALBERTA

PREDICTION AND IDENTIFICATION OF POSSIBLE HEARING IMPAIRMENT IN ALBERTA HEALTH UNITS: CAN POSSIBLE IMPAIRMENTS BE DETECTED PRIOR TO ROUTINE KINDERGARTEN PURE-TONE AUDIOMETRIC AND IMPEDANCE SCREENING?

BY

(C) PATRICIA BLAIR

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF EDUCATION

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Identification and Prediction of Possible Hearing Impairment in Alberta Health Units: Can Possible Impairments be Detected Prior to Routine Kindergarten Pure-Tone Audiometric and Impedance Screening? submitted by Patricia Blair in partial fulfilment of the requirements for the degree of Masters of Education in Educational Psychology.

(Supervisor)

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ABSTRACT

This study proposed to develop a model of prediction of possible hearing impairment, which could function to supplement routine pure-tone and impedance testing completed by some Alberta health units at the age of kindergarten entrance. The health charts of 426 children below the age of 5 1/2 were analyzed in terms of prenatal, perinatal and early childhood history present in the charts. Few factors were found to differentiate those who passed and those who failed pure-tone and impedance testing completed in kindergarten. The presence of middle ear pathology, allergies, gestational age of 35 weeks or less, and failures of the gross motor, fine motor-adaptive and language scales on the Denver Developmental Screening Test at 3 1/2 years of age were the only variables found to possess any predictive value for possible hearing impairment.

As a result, it was recommended that rather than developing a predictive model based on a very limited number of variables, two of which appear on most high risk registers, hearing screening programs in public health commence their testing at age 3 1/2 years, utilizing pure-tone audiometric, impedance, and developmental testing.

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CHAPTER I

SUMMARY OF PROBLEM

The need for early and reliable identification of any disorder which manifests itself in childhood is an issue of growing concern in medical, rehabilitative and educational circles alike. Whether the particular disorder be one of global retardation, autism, or one of a perceptual nature, there exists increasing consensus that the earlier a diagnosis can be established, the sooner formal and/or informal intervention can be implemented in an attempt to minimize the negative effects of the disorder (Lloyd, 1976; Skinner and Shelton, 1978; Moores, 1978). Childhood hearing impairment, both conductive and sensorineural, is an example of such a disorder.

In recent years, therefore, the early identification of hearing impairment in children has been the focus of much attention. Health and Welfare Canada, for example convened a Task Force to study this topic and to attempt to deal with some of the difficulties encountered with the early identification of hearing loss (1984). In addition to the need for reliable detection procedures, financial, procedural and theoretical problems continue to plague the institution of such practices being established in public health. Data collected as recently as 1983 indicate that as many as 50% of congenitally deaf children go undiagnosed until they reach the chronological age of three years. Given that total deafness is more easily detected than a partial loss, it is reasonable to assume

that greater than 50% of those children born with a partial loss go undetected in the first three years of life, depending upon the level of detection services available in their geographic region. The major urban centres are much more likely to possess more sensitive equipment and more comprehensive services than are the more sparsely populated rural regions of the country (Peacock and Horowitz, 1983).

The question yet to be answered, therefore, is how to more effectively and reliably predict and/or detect childhood hearing impairment without far exceeding the financial resources of local health authorities. As a part of routine preschool screenings carried out by public health authorities in Alberta and in much of Canada, various data are collected relating to perinatal and postnatal history, biographical information on parents and family, and results of developmental screens, utilized to assess motor, verbal and cognitive skills of the child. Given these data, is it possible for them to be considered in relation to each? For example, do children who fail a hearing screening test during the preschool years exhibit a historical pattern of development which is different from the developmental pattern of those possessing normal hearing acuity? Since these data are collected on a routine basis in the present systems, it would be valuable to know if the data provide any prediction model for the screening, both early and reliable, of childhood hearing impairment, which might be used to supplement the pure-tone audiometric screening completed in

kindergarten. This study, therefore, will examine the health history as it is present in the public health records of children who passed the kindergarten pure-tone screen, in addition to those who failed. The failure group will be sub-divided into those who failed pure tone testing unilaterally, bilaterally, those who failed impedance only and/or those who failed both the pure tone and impedance screens. It must be reiterated, that this type of data can be valuable only as a supplement to, rather than a replacement for pure-tone audiometric screening.

CHAPTER II

REVIEW OF THE LITERATURE

The need for early and reliable identification of any disorder which manifests itself in childhood is an issue frequently dealt with in the literature. Whether the particular disorder of interest be one of retardation, autism or of a perceptual nature, it is the general consensus of the literature that the earlier a diagnosis can be established, the earlier formal and informal intervention can be implemented in an attempt to minimize the effects of the disorder (Lloyd, 1976; Skinner and Shelton, 1978; Moores, 1978). A particularly lucid example of this trend is that of learning disabilities. Until the past decade, children possessing soft, subtle signs indicative of many learning disabilities were not identified, frequently reaching adulthood being non-functional in one or more of the skills they were presumably taught in school. In recent years, with increased research efforts and the development of more sensitive testing instruments, these children are being identified earlier in their academic lives, with attempts being made to provide remedial instruction as early as possible. Again, the justification for this increased identification effort is the minimization of later detrimental effects resulting from the disorder, in addition to a greater degree of plasticity during early development. After all, it is reasonable to acknowledge the difficulty faced in providing compensatory and/or remedial services at a young age if the disorder is not identified or detected. One

discipline continuing to struggle with this very problem is that of audiology. Few in the area would argue against the need for early identification of a hearing impairment. Parving (1984) for example, an audiologist from Denmark, a country which at present is making great strides in the remediation of this identification problem, cites the need for improved early detection and identification to reduce both severity and frequency of disorders in speech, language, psychological and mental behavior. The Canadian Task Force on Childhood Hearing Impairment (1984) set out several recommendations dealing with early detection, including the utilization of a high risk register, and cited the need for procedural guidelines for professionals in addition to the need for an expansion of services particularly in rural regions of the country. In additional studies, researchers such as Peacock and Horowitz (1983) also considered this need, stating that early detection is of paramount importance to enable the provision of suitable auditory aids to help in the development of speech, language, and later, general educational development. These same authors go on to discuss a study undertaken by the Commission of the European Community (1979) which found that fewer than 50% of congenitally deaf children were diagnosed before three years of age. This finding should not be taken lightly. If one takes the term "congenitally deaf" in a literal sense, it refers not to children possessing a partial or intermittent loss, but rather to those whose hearing has not been functional for everyday purposes

since birth (Skinner and Shelton, 1978). With increasing evidence that the greatest degree of growth and development takes place within the period from birth to three years of age (Caldwell, 1970), the detrimental effects of such findings cannot be overstated. Further to this point, as long as eighteen years ago, Pollack (1967) stressed the importance of fitting a hearing impaired child with a hearing aid as soon as possible after identification of the impairment. She continued that in no case of congenital deafness should this occur later than the age of six months.

Clearly, the need to identify hearing impairment as early as possible is agreed upon, whether it be for the purposes of fitting an aid or for providing educational and/or medical intervention (Joint Committee on Infant Hearing Position Statement, 1982). The difficulty arises when considering how, in fact, to meet this need (FitzZaland and Zink, 1984). This paper will attempt to address this problem of identification and screening techniques. The inclusion of these predictive factors in high risk registers used to identify those children susceptible to such disorders of hearing will be considered, as will current screening and diagnostic procedures. Their contributions and drawbacks will be discussed.

Hearing Impairment and Related Factors

The cause or etiology of a hearing impairment cannot always be isolated (Skinner and Shelton, 1978). Frequently, a hearing impairment will occur in the absence of any other identifiable

aberration. No physical abnormality can be detected, nor can any other possible cause of the impairment be pinpointed. In fact, approximately 30% of all hearing impairment falls into this category, characterized by unknown etiology (Bensberg and Sigelman, 1976). This very fact makes any prediction of a hearing impairment, in one third of all cases, based on nothing more than chance occurrence, leaving two thirds of cases at least partially attributable to some genetic, prenatal, perinatal or postnatal event. Of that remaining two thirds of cases, approximately one third is genetically transmitted, leaving one third attributable to various infections or traumas experienced prior to or near the time of birth (Figure 1).

INSERT FIGURE 1 ABOUT HERE

Genetic Factors

In the majority of instances of hearing impairment attributable to genetic etiology, the impaired individual otherwise develops normally (Moores, 1978). In these cases, the presence of a hearing deficit is solely determined by the laws of genetics; that being the expressivity of recessive and dominant genes. For example, a child displaying recessive congenital deafness is generally a child whose parents both have normal hearing but are, unfortunately, both carriers of the genes for deafness. In reviewing the simple laws which govern genetic transmission, it becomes clear exactly how this situation occurs (Figure 2).

Figure 1 has been removed due to inability to obtain copyright permission. Figure 1 consisted of a distribution figure of etiology of hearing impairment, including genetic, disease, drugs and trauma.

From Hearing Impairments in Young Children (p. 24), by A. Boothroyd, 1984, Prentice-Hall Inc. Copyright 1984 Prentice-Hall.

INSERT FIGURE 2 ABOUT HERE

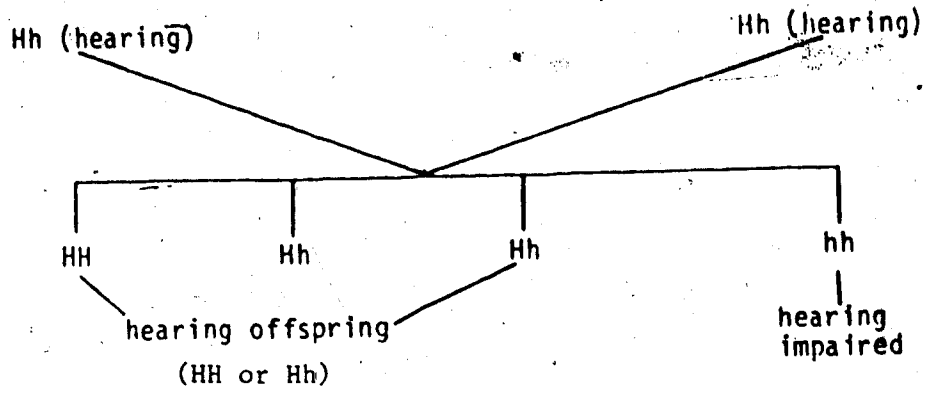
From this Figure, it can be seen, for a child whose parents are both hearing but do carry the gene for recessive deafness, there exists a 25% risk that that child will be hearing impaired (hh). Fifty percent of resultant offspring would possess normal hearing though remain carriers of the recessive gene (Hh). Finally, 25% of these offspring would indeed exhibit some degree of hearing impairment. It is not, however, merely a single gene which determines the presence or absence of recessive congenital deafness. There exist, in fact, thirty to one hundred and fifty recessive genes for deafness present in the general population (Brown, 1967). Chung and Brown (1970) stated that of these, four or five relatively common ones produce most cases of recessive congenital deafness. Therefore, since the recessive genes can occur at differing genetic loci, the 25% figure relating to the occurrence of recessive deafness is high. It is felt, however, that one out of every four or 25% of persons in the general population is a carrier for at least one recessive gene which has the potential of resulting in childhood deafness (Brown, 1967), thus accounting for 40% of genetically transmitted early childhood deafness.

Constituting another 10 - 15% of those exhibiting early childhood hearing impairment are those affected by dominant congenital deafness (Konigsmark, 1972). In this type of situation,

FIGURE 2 Genetic Transmission of Hearing Impairment

H = gene for normal hearing

h = recessive gene for deafness



Adapted from Educating the Deaf: Psychology, Principles and Practices (p. 87), by D. Moores, 1978, U.S.A.: Houghton-Mifflin. Copyright 1978 by Houghton-Mifflin Company.

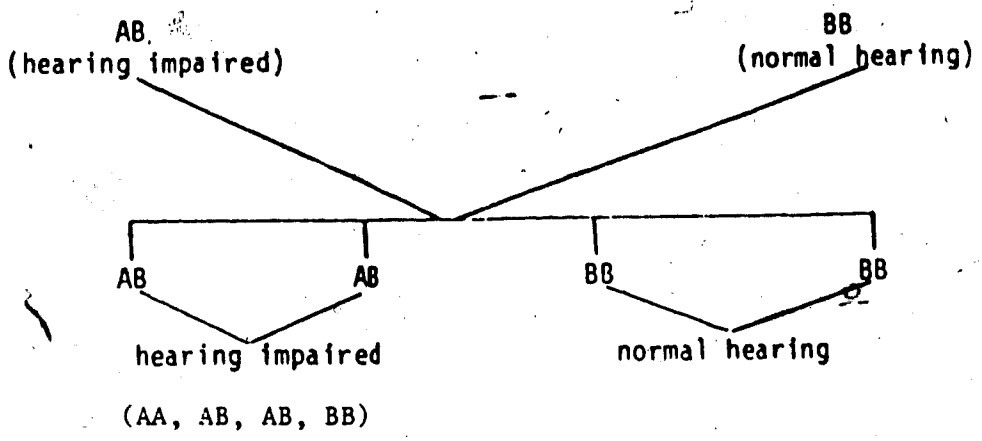
only one gene, dominant in nature, is needed for the deficit to be manifested. The manifestation of the impairment, however, is partially governed by the concept of penetrance (Moores, 1978). This refers to the actual proportion of cases in which the disorder is manifested even in the presence of the dominant gene. For example, a child being born to parents, one of whom was hearing impaired, that child would have a 50% chance of being hearing impaired (Figure 3).

INSERT FIGURE 3 ABOUT HERE

In actuality, the proportion is somewhat lower than 50%. Consider, for example, Waardenberg's Syndrome, a condition characterized by widely set apart eyes and a streak of white hair above the forehead, and often, a congenital hearing impairment. Oddly enough, though the dominant gene for deafness is present, a hearing impairment is manifested in only 20% of cases (Brown, 1967).

In rounding out this consideration of genetically determined hearing impairments, attention should be brought to another syndrome which is frequently accompanied by a congenital conductive hearing loss. Treacher-Collins Syndrome results in the malformation or absence of the external ear and incomplete formation of the external ear canal. Frequently the middle ear is also affected in Treacher-Collins Syndrome.

FIGURE 3 Genetic Transmission of Hearing Impaired (2)



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Other Related Factors

As previously stated, the remaining factors and conditions associated with childhood hearing impairment can occur either prenatally, perinatally or postnatally.

According to 1972-73 statistics (Hudgins, 1973), maternal rubella accounts for the largest proportion of non-hereditary cases of childhood hearing impairment (Table 1).

INSERT TABLE 1 ABOUT HERE

The contraction of maternal rubella within the first trimester of pregnancy, or, on occasion, later in pregnancy, can result in damage to the unborn child. The severity of this condition, depending on when it is contracted by the mother can actually result in the death of the fetus, by crossing the placental barrier and attacking the growing cells. Areas most frequently involved are the eyes, ears and heart, though hepatitis, anemia and disturbed bone development have also been reported (Hardy and Bordley, 1973). In 1973, Hardy and Bordley studied three hundred confirmed cases of rubella and reported that 40% of these did, in fact, manifest some degree of hearing impairment, while 25% had heart defects, 20% had visual abnormalities, 60% showed slow motor development and 50%

TABLE 1

1972-73 Statistics on Etiology

CATEGORY	NUMBER	PERCENTAGE
Acquired deafness	95	45.03
Rubella	51	24.17
Blood Incompatibility	14	6.64
Prematurity	12	5.69
Meningitis	8	3.79
Other	6	2.84
Congenital	48	22.75
Unknown	68	32.23

Note: Adapted from Educating the Deaf: Psychology, Principles and Practices (p. 84), by D. Moores, 1978, U.S.A.: Houghton-Mifflin.

displayed poor physical development. A hearing impairment resulting from maternal rubella is generally sensorineural in nature, rendering it untreatable through surgery.

One difficulty which arises when attempting to use maternal rubella as a predictor of hearing impairment in the infant is the fact that frequently the woman is unaware that she has contracted the disease. Hardy, Haskins, Hardy and Shimiz (1973), found that as many as 37% of infected mothers were not aware that they had contracted the rubella virus until it was confirmed by routine laboratory tests. Thus, many cases go undetected, and in all likelihood, account for a sizable proportion of those cases precipitated by unknown causes.

Accounting for a somewhat lower proportion of acquired hearing impairment is Rh blood incompatibility (Moores, 1978). This situation occurs in instances in which the mother's blood is Rh negative, while the newborn's is Rh positive. Though not critical in the first nor often the second pregnancy, by the third pregnancy the mother's body has had the opportunity to build up antibodies designed to kill Rh positive cells. With improved medical services, this situation can generally be compensated for, however, if left undetected, can result in a significant sensorineural hearing impairment (Bensberg and Sigelman, 1976).

Another condition which is on the decline due to increased medical knowledge is meningitis (Moores, 1978). At one time, meningitis alone accounted for 27% of all childhood deafness. It can

be transmitted via a variety of infectious agents including bacteria, fungi, virus and spirochaetes (Kelly, 1964). Approximately 50% of all cases of meningitis occur in children under the age of five years, and it continues to be the leading causal factor of non-congenital school aged hearing impairment (Hudgins, 1973).

Though there exist many other conditions which can result in hearing impairment (mumps, measles, scarlet fever, whooping cough, congenital syphilis) when contracted in utero, infancy or early childhood, they account for only a small proportion of reported cases (Bensberg and Sigelman, 1976).

The relation of all these previously cited factors to hearing impairment appears to be conclusive and reliable. This is undoubtedly due to the great amount of study and evaluation of medical records over a lengthy time period. Unfortunately, this does not hold true for all factors thought to be related to childhood hearing impairment. For example, the controversy surrounding prematurity as a causal factor continues to rage on. Desmond and Rudolph (1970) concluded that such factors as lower socioeconomic status, poor prenatal care, maternal usage of drugs, alcohol and tobacco are all associated with prematurity. Furthermore, the under-developed child is more vulnerable to injury during the birth process, including intracranial bleeding and anoxia. It is felt that any one or combination of these factors could indeed result in a hearing impairment, rather than the deficit being directly attributable to prematurity per se.

Trends For The Future

If any of these factors are to be utilized as high risk criteria for early childhood hearing impairment, screening procedures which tap projected incidence rates and acknowledge the advancement of medicine must be developed. For example, it may be predicted that the incidence of hearing impairment due to Rh incompatibility will decline due to improved health care and prenatal monitoring, and thus alter the emphasis that detection of this condition is given in an identification program. It is not, however, an easy task to make reliable predictions of this type. The discovery of penicillin as an example, produced predictions that the incidence of hearing impairment due to congenital syphilis would decline significantly. At that point in time, researchers had no indication that a change in sexual morality was about to occur. With a new wave of liberalism, sexual activity among unmarried couples increased, thus increasing the opportunity to contract syphilis, while at the same time, oral contraceptives began to replace the condom as a primary birth control method. Therefore, rather than decreasing in number, the number of hearing impairments as a result of congenital syphilis actually increased due to external influences which were neither expected or predictable (Bensberg and Sigelman, 1976).

It can be easily discerned from this previous discussion of factors that there does indeed exist a large variety of associated factors, some of which are more predictive of hearing impairment than others. The question yet to be examined is one of how to organize

these data into a manageable framework which can be implemented in facilities providing infant and preschool health service. This has, in fact, been attempted through the utilization of high risk registers and screening procedures, with early identification being the end goal.

High Risk Registers and Screening Procedures

One cannot adequately discuss hearing screening procedures without first examining the use of high risk registers. The implementation of screening programs used to detect hearing impairment has been documented in the literature since 1967. Since its appearance at that time, it took only two years for early researchers in this area to realize the need for high risk registers to be used in conjunction with the screening procedure, in an attempt to reduce the massive numbers of children being screened (Downs and Hemenway, 1969). In both Canada and the United States, high risk registers for hearing impairment have undergone substantial revision since their inception some eighteen years ago. At present, as far as the current literature would indicate, North America is utilizing a register set forth in 1982 by the Joint Committee on Infant Hearing, which was presented in their position statement pertaining to identification of hearing impairment (1983). Those factors cited were also cited and advocated by the Task Force on Childhood Hearing Impairment (1984). This Joint Committee, consisting of representatives from pediatrics, otolaryngology, nursing and speech and language, generated the following to serve as the basis for a high risk register to be utilized in the identification process:

1. Family history of childhood hearing impairment.

   This category would presumably identify those 10 - 15% of children who are at risk for dominant childhood deafness, as one family member at some point would have manifested a hearing impairment. The likelihood of it identifying a child at risk for recessive childhood deafness would be expected to be somewhat less, as the recessive gene may have been passed down through several generations without any manifestation of the impairment.

2. Congenital prenatal and perinatal infection (rubella, herpes, syphilis).

   It is reasonable to infer that this item would detect those children whose mothers had contracted an infection during the course of her pregnancy. As noted previously, though, it is not unusual for a woman to be unaware that she had contracted rubella for example. In the case of herpes and syphilis, is it not realistic to assume that a sizable proportion of women would be reluctant to report contracting the disease when asked by a clinic nurse or hospital screener? Therefore, there may exist a larger number of undetected risk cases resulting from infections.

3. Anatomic malformations of the head or neck.

   In relation to the prediction factors discussed earlier, this category would encompass those children displaying various syndromes which involve abnormalities of the ear, tongue, lip and palate.

4. Bacterial meningitis.
5. Birthweight under 1500 grams.
6. Hyperbilirubinemra levels.
7. Severe asphyxia which may include infants with Apgar scores of zero to three or who fail to institute respiration by ten minutes and those with hypotonia persisting past two hours of age.

Items 5, 6 and 7 fall into a group of characteristics which are associated with prematurity, though can occur in a full term baby. In the past, high risk registers have lumped these together under the risk item prematurity, however, recent studies have indicated it is not the prematurity per se which causes the hearing impairment, but rather, certain conditions associated with prematurity. A premature child, for example, is more vulnerable to birth injury, anoxia which may in turn result in a hearing impairment (Moores, 1978).

This high risk register appears to address most of those factors which have some degree of predictive value. It is clear, however, that a register such as this is apt to miss those children suffering from impairments attributed to recessive congenital deafness, to some degree those resulting from rubella and other maternal infections, and finally, those resulting from an unknown etiology. If one was to calculate the percentage of hearing impairments which could go undetected as a result, the number would be a disconcerting 56% based on Moores (1978) incidence levels.

Any child manifesting at least one of the items included in this high risk register would be considered a potential candidate for

early childhood hearing impairment. Once identified as such, several outcomes may occur. Prior to the 1982 position statement issued by the Joint Committee, Canada's recommendations for identification of hearing impairment included the utilization of a high risk register resembling that which was later set forth by the Committee (Jacobson, 1979). In addition, the following statement was made. "As a supplement to the high risk register, an agency may employ behavioural screening tests (Jacobson, 1979, p. 204).

In 1982, the Joint Committee provided expanded guidelines, though still not specifying the type of testing to be used in follow-up. In general terms, they stated that any child manifesting any of the items found on the high risk register should undergo a hearing screening under the supervision of an audiologist, optimally by three months of age. The type of screening device which should be utilized was not specified, other than to say it should include behavioural observation or electrophysiologic responses to sound. For those children failing the screening, the Joint Committee recommended a diagnostic evaluation of hearing. Thus, a child failing the screening should, by six months of age, be involved in:

1. General physical examination and history including:
   a) examination of head and neck
   b) otoscopy or otomicroscopy
   c) identification of physical abnormalities
   d) laboratory tests for perinatal infections
2. Comprehensive audiological examination
   a) behavioural history

b) behavioural observation audiometry

c) testing of auditory evoked potentials

In addition to these, the following evaluation should be completed periodically after the age of six months.

1. Communication skills
2. Acoustic Impedance
3. Developmental Testing

Due to the relatively short time period since the publication of this position paper, there is little evaluative data present in the literature which deals with the implications of the statement. Of that which does exist, both advantages and disadvantages of the recommendations can be seen. Stein, Clark and Kraus (1984) considered infants in neonatal intensive care units as compared to those attending well baby clinics. They reported that of those children being followed by intensive care units, the most frequently reported risk factor for hearing impairment was birthweight less than fifteen hundred grams, while infection, meningitis and family history were the most frequently cited factors for those children being followed by well baby facilities. Moreover, they found that overall, the cause of the hearing impairment could not be identified through either hospital records or parent interviews in 29.5% of the cases. This statistic rose to 46.5% when considering the well baby group alone. Thus, their results concur with the previous estimate of the numbers of cases going undetected by a high risk register.

An additional significant finding of the Stein et al. (1984) study, relates to the age of intervention. The Joint Committee's

position paper (1983) stressed the need for identification of hearing impairment prior to the age of six months. This is to ensure that intervention can occur to the earliest possible opportunity. Stein, found that only 11% of their sample was identified and enrolled in some type of intervention program by the age of six months. They found, in fact, that the median age for this to occur was in reality, closer to the eighteen month range, regardless of whether the loss was detected by an intensive are unit or a well baby clinic. Why is this the case? These researchers offered no answers to that question other than a lower socioeconomic level of their sample. There do, however, exist other possibilities. Is it not possible that the screening which was carried out was not done so under the supervision of an audiologist as was suggested by the Joint Committee? There were no guidelines relating to what qualifications the tester should possess in the absence of an on-site audiologist. Secondly, since no specific tests or testing procedures were defined or explained, is it not possible that unreliable or invalid testing was to blame? These are just two issues in great need of further investigation.

Parving, (1984) addressed similar issues to that of the Stein, et al., (1984) study in his own research. Through the use of questionnaires distributed to parents of hearing impaired children, Parving generated the following conclusions based on his sample:

1. In 59% of cases, the parents were the first to suspect the child's hearing loss, with family history being the most frequently cited indicator.

2. In only 13% of cases, did those hearing impaired children fail the screening.
3. Sixteen percent of the children were registered as high risk, thus Parving concluded that the registry was highly inefficient.
4. In 43% of instances, a period of at least four weeks passed between the first suspicion of the loss and any valid audiological testing, with 59% of those delays being attributed to lack of belief in parents' reports on the part of the health professional.
5. The median age for a hearing threshold assessment was twenty months.
6. Only 33% of those hearing impaired children were diagnosed as such by one year of age.

Parving (1984), on the basis of this data concluded that identification of the hearing impairment, in most cases, was unacceptably late. Moreover, Parving stated;

> This screening ~~by~~ the parents exhibits a methodological sensitivity that equals that of many systematic hearing screening procedures. Although one of the important effects of the systematic hearing screening procedures may be an increased awareness of auditory function, it may on the other hand give rise to a dangerous false security of intact hearing based on a false pass of the screening test (Parving, 1984, p. 114).

In consideration of these statements, it becomes clear that several problems remain yet unresolved. Included among these is the inefficiency of high risk registers in the detection of some factors predictive of a hearing impairment. Improperly trained staff and poor testing procedures have also come under attack. In respect to

the latter of these, it is crucial to evaluate the difficulty and expense involved in the implementation of many of the testing procedures. Alexander, Coulling and Coulling (1976), in addition to inadequately trained testers, offered poor testing environments and the low incidence of hearing impairment as explanations for these difficulties. Thus, prior to the establishment of a hearing screening program, it is essential that the various testing options and protocols be examined in detail to meet with the needs of both the target population and the facility providing the service. For example, the Joint Committees' position statement (1983) recommended either behavioural or electrophysiological observation of responses to sound. In what ways, using what equipment can this be best achieved?

Behavioural observation audiometry, according to Alberti, Hyde, Corbin, Riko and Abramovich (1983), has been the most frequently utilized form of screening for hearing impairment. Two distinct advantages of this technique include simplicity and short administration time. The major drawback however, is that this method has, in the past, generated high false negative rates. Alberti et al., reported that these have been as low as 40% and as high as 74%. Why is it that such a larger proportion of hearing impaired children pass the screening undetected? This is a complex question for which the possible explanations are equally as complex. In consideration of the literature on behavioural testing, one characteristic and possible explanation becomes dominant. There appears to be very little consistency across screening programs in the type of

behavioural testing being completed, the stimulus and response criteria or the scoring procedures. Secondly, recommended testing devices and procedures change with the various ages of the population being screened. Perhaps a few examples will illustrate these two points more clearly. Peacock and Horowitz (1983) discussed procedures for hearing screenings which are being utilized in the United Kingdom. In their opinion, the ideal age to carry out this screening is eight months, at which time a localization test should be administered. They described this behavioural test as a simple one, though one easily invalidated. In short, this type of testing involves placing the baby being screened on the mother's knee, creating a bored state, and monitoring the baby's responses to sounds produced by various tests. These test include:

1. a cup stroked gently with a spoon
2. a high frequency rattle
3. a repeated /s/ sound
4. an "oo" vocalization

These stimuli are presented out of the child's visual field at 40 dB, at a distance of one meter from the ear and on the same horizontal plane as the ear. According to these researchers, a positive or passing response would be any localization to the sound source by the baby. Eye glances or random head movements however, do not constitute a passing response. Peacock and Horowitz did provide some words of caution when administering this test. They stated that the 40 dB threshold level is difficult to achieve and requires constant practice. Presumably, then, it would be adversely affected

by ambient room noise. They also stated that babies at this age are unable to localize sound above or below the horizontal plane of the ear. Additional considerations which arise are unintentional cueing through shadows or accidentally re-entering the baby's field of vision. They feel in summary, however, that these tests do indeed provide very accurate results and should not be replaced by other such devices as cradle or crib indicators. Jacobson and Morehouse (1984) agree with this latter point. In their discussion of behavioural screening, they considered the utility of an automated behavioural screening instrument, the Crib-O-Gram, With respect to their particular sample, they found it to be sensitive to only 52% of hearing impaired children; whereas Mencher (1977), cited the Crib-O-Gram as having good reliability and validity and being a useful tool for otherwise unresponsive children.

Shepard (1983) reported significantly better results with a similar automated device named the Linco-Bennett Auditory Response Cradle. In his pilot study, Shepard utilized a high risk register in conjunction with multiple channels of behavioural responses which were somewhat more clearly defined than those utilized by Peacock and Horowitz (1983). Shepard used three independent motor and two respiratory response channels which monitored total body movement, head jerk or startle response, head turn, respiratory and cardiac reactions to sound presentations. The technical details of this system are beyond the scope of this paper, but are well documented in Shepard's article.

As an outcome of Shepard's (1983) study, he concluded that the implementation of the response cradle was a cost efficient program, which when used in conjunction with a high risk register, was able to provide optimum detection of hearing impaired children who might otherwise pass undetected through less sophisticated screening methods. Shepard also stressed the appropriateness of using this device with newborns, unlike many other behavioural methods which remain relatively unreliable until the child is at least six months of age (Peacock and Horowitz, 1983; Shepard, 1983). An example of this is the use of pure-tone audiometry, used routinely with children of three years and older.

It can be seen that among the numerous techniques being utilized, little uniformity exists. Behavioural observation techniques can range from the utilization of calibrated rattle to a sophisticated automated device; likewise responses can vary between an acceptance of eye movement, non acceptance of eye movement, to cardiac and respiratory alterations (Table 2).

INSERT TABLE 2 ABOUT HERE

Jacobson (1979) in an attempt to provide some degree of uniformity, published a suggested protocol of a behavioural hearing screening test for young children, this being as a response to the

Table 2 has been removed due to inability to obtain copyright permission. Table 2 outlined age and stimulus guidelines for hearing screening techniques.

From Early Identification of Hearing Loss (p. 82), by G.T. Mencher, 1976, Switzerland: S. Karger, Copyright 1976 by S. Karger.

lack of consistency among program procedures. He stipulated the following:

1. Test Stimulus

   A random noise having a low-frequency attenuation of 30 dB. This would presumably leave the actual stimulus item up to the tester, as long as it qualified under this guideline.

2. Infant Response

   Any generalized body movement which involves more than one limb and is accompanied by some form of eye movement.

3. Scoring Criteria

   To be controlled by one of two methods:

   a) scorer does not know when the stimuli is presented

   b) two independent scorers

4. Pre-Test State

   Jacobson stressed the pre-test state of the child would depend on the particular stimulus being utilized but should, in all cases, be controlled or described in specific terms.

5. Test Environment

   Some measure of ambient room noise should be taken.

These guidelines then, could be applied to either automated or non-automated devices, startle, localization or behaviourally trained responses and an alert or sleeping pre-test state. The critical factor would appear to be the strict adherence to the operationally defined procedures of scoring, response judgement and test administration.

Behavioural observation techniques are not the only type of testing which is currently being implemented in hearing screening programs. One of the newer techniques is that of using Auditory Brainstem Responses (ABR) as a screening tool (Hooks and Weber, 1984). In the past, this has been a procedure more commonly utilized as a diagnostic tool. The major drawback to using ABR as an early screening device is that due to the immaturity of the neurological system at this age, there can be a high rate of false positives. In the past few years, this type of testing has utilized bone conduction as well as air conduction tests. Hooks and Weber felt that as the sophistication of bone conduction ABR improves, it will become a feasible technique to use with premature and at risk children. This would be beneficial in two ways. Firstly, it would serve to reduce the number of false positives which are common in air conduction ABR testing. Secondly, being able to compare air and bone conduction results, the type of loss could be determined. As a result, the need for continued retesting of conductive losses could be eliminated and a monitoring program of follow-up be implemented. Consequently, in time, a great deal of money could be saved from the decrease in numbers of repeated screening. Jacobson and Morehouse (1983), concurred with this view, and stated that if appropriate testing protocol was utilized, ABR could be a valid screening device. Once again Jacobson called for control in testing.

Finally, Hyde, Riko, Corbin, Moroso and Alberti (1984) reported similar findings using ABR as a screening procedure. These

researchers felt that due to the inadequacies inherent in behavioural tests, these cannot be used to validate ABR, thus normative data may become problematic. In summary, however, they too felt that ABR is an excellent estimator of perceptual thresholds and remains relatively easy to carry out as the infant is in a sleeping pre-test state.

Unfortunately, however, not all facilities are equipped with such sensitive detection devices. This is the case with most public health facilities in Alberta. Many public health clinics routinely conduct well-baby clinics, at which time developmental testing is completed. Between age 56 and 70 months, audiometric screening is conducted. For the purposes of this study, it will hereafter be referred to as a kindergarten audiometric screen. This involves pure-tone air conduction testing which is carried out by nursing staff, health aides or the speech-language pathologist. In 1982, Health and Welfare Canada established guidelines for this type of screening procedure. These guidelines, similar to those later imposed by the American Speech and Hearing Association (1985) state:

1. Individual as opposed to group screening is recommended.
2. Pure-tone signals shall be used.
3. Test frequencies shall be 1000 Hz, 2000 Hz, and 4000 Hz.
4. Screening levels shall be 20 dB HL (re: ANSI-1969) at 1000 Hz and 2000 Hz and 25 dB at 4000 Hz.
5. Failure to respond to the recommended screening levels at any frequency in either ear shall constitute failure.

6. All failures should be rescreened preferably within the same session which they failed but definitely within one week after the initial failure.
7. Failures on rescreening should be referred for audiologic evaluation by an audiologist.

The following referral priority for audiologic evaluation is recommended:

a) Binaural loss in both ears at all frequencies
b) Binaural loss at 1000 or 2000 Hz only
c) Monaural loss at all frequencies
d) Monaural loss at 1000 and 2000 Hz only
e) Binaural or monaural loss at 4000 Hz only

In addition to these guidelines, the expert group for Health and Welfare Canada (1982) also discussed some pertinent procedural considerations. Following ASHA guidelines, the group called for these identification programs to be conducted or supervised by an audiologist, hopefully eliminating the invalidation of testing when administered by inadequately trained staff. The group also stressed the need for careful instruction, including emphasizing the importance of responding "right away even when the beep sounds far away" (ASHA, 1982, p. F4). In addition to these aforementioned considerations, the expert group pointed out the importance of the testing environment. Ambient room noise can easily affect test

results, and in most cases, adversely. Calibration and maintenance of the audiometer utilized for screening must also be ensured.

In some Alberta health units, acoustic immittance screening of middle ear function is completed in addition to the pure-tone audiometric screen. The American Speech and Hearing Association (1979) has put forth guidelines governing this type of screening procedure. The purpose of these guidelines was to recommend procedures and parameters for accomplishing fast and efficient identification of middle-ear dysfunction. The procedural considerations established by ASHA included:

1. These programs should be under the direct supervision of appropriately qualified professionals, including audiologists, physicians and speech-language pathologists.
2. The screening procedures should be administered annually to children of nursery-school age through grade five. Routine screening for children younger than seven-months of age is not recommended.
3. Appropriate calibration of equipment must be ensured.
4. An automatic constant-rate pump system with a recording system is recommended.
5. The recommended air pressure should cover a minimum of +100 to -300 m. H_2O.
6. A low frequency probe-tone between 220 and 300 Hz is recommended.
7. The recommended eliciting signal is a pure-tone of 1000 Hz.

8. Levels recommended are a 100 dB HL signal for contralateral stimulation or a 105 dB SPL signal for ipsilateral stimulation.
9. The acoustic reflex test should be administered at the tympanogram peak pressure point.
10. For screening purposes, middle ear pressure, and presence or absence of the acoustic/reflex, are the only factors involved in referral criteria. Pass/fail criteria can be seen in the following chart (Figure 4).

INSERT FIGURE 4 ABOUT HERE

ASHA recommends the utilization of the following chart to appropriately deal with tympanometric testing (Figure 5).

INSERT FIGURE 5 ABOUT HERE

These guidelines are followed by some health units in Alberta.

Clearly, many screening devices exist, each possessing advantages and disadvantages. The bulk of the literature would suggest that the behavioural observation techniques suffer from problems including poorly defined stimuli and response criteria,

FIGURE 4 Middle Ear Screening Criteria

Classification	Results of Initial Screen	Disposition
I. PASS	Middle-ear Pressure Normal* or Mildly positive/ negative** and Acoustic Reflex Present***	Cleared, no return
II. AT RISK	Middle-ear Pressure Abnormal**** (and Acoustic Reflex present or Acoustic Reflex Absent (and middle-ear pressure normal or mildly positive/negative)	Retest in 3 - 5 weeks a) If Tymp. and AR fall into Class I, PASS b) If Tymp. or AR remain in Class II FAIL and refer.
III. FAIL	Middle-ear Pressure Abnormal and Acoustic Reflex Absent	Refer
IV. Questionable	Non-compliant behavior	Retest

* Normal: Pressure peak in range ± 50mm H_2O.

** Mildly Positive/Negative: +50 to +100 mm H_2O -50 to -200mm H_2O.

*** Present: Pen or meter needle deflection judged to be coincident with the reflex eliciting stimulus at levels of 100 dB HL for contralateral stimulation, 105 dB SPL for ipsilateral stimulation at 1000 Hz

**** Abnormal peak outside the ranges described for Classification I.

Adapted from American Speech and Hearing Association (p. 286), 1979.

Figure 5 has been removed due to inability to obtain copyright permission. Figure 5 depicted referral procedures following an initial hearing screening.

From American Speech and Hearing Association (p. 287), 1979. Copyright 1979 by ASHA.

inadequately trained testers, and poor scoring techniques. They are, however, quick and inexpensive to administer.

It would appear that as more effort is put into the development of improved screening techniques, Auditory Brainstem Response testing will come to the fore. This technique is the most frequently cited technique seen as having the potential to be a feasible part of a hearing screening program, especially with those children too young to respond reliably to pure-tone audiometry which is used in conjunction with routine impedance testing to screen older children (Cox and Lloyd, 1976).

Summary

The prediction of a hearing impairment is not a simple task. It involves the consideration of many factors including etiology of the impairment. Since in 30% of instances, the cause of a hearing impairment is unknown, the accuracy of any prediction on the basis of etiology alone is seriously decreased. The prediction factors generated through the study of etiology have been put into the framework of high risk registers in an attempt to identify at least some of those at risk for hearing impairment. In this way, massive numbers of screenings can be avoided, while those seriously at risk will not be overlooked. Unfortunately, many hearing impaired children do not fall into the categories of at risk factors listed in the registers.

To supplement the register, hearing screening techniques have been implemented to routinely test the hearing of those children identified by the registry. Unfortunately, these testing procedures are plagued with problems including poorly defined stimulus and response criteria, inadequately trained testers and poor scoring procedures. It is hoped that in the future, Auditory Brainstem Response testing will solve many of these difficulties. Since behavioural observation techniques will in all likelihood fail to detect losses less than 75 dB HL much hope is being placed in ABR (Mencher, 1976).

In the past, many institutions, and health care facilities have implemented screening programs. Examples of programs include the Colorado Screening Project (Downs, 1976), BOEL, A Child Welfare Program for Early Screening of Communication Abilities (Glorig and Curtis, 1976) and a Three Stage Hearing Testing Programme for Children in Poland (Borkowska-Gaertig, Urbanska, Sobieszczanska-Radozewska, Rola-Janici, 1976), and the Canadian Health and Welfare Task Force on Childhood Hearing Impairment (1984). At this point in time, they generally all recommend similar actions for the future. They indicate the need for further evaluative study of hearing screening programs which must be used in conjunction with high risk registry, staff and public education of hearing impairment, and techniques which strive to tap the valuable information which only parents can provide. Which factors need to be the focus of investigation? High risk registers, with their inclusion of various

genetic, behavioural and social considerations, clearly play a significant role. There are numerous factors which have been shown time and time again to be significant indicators of increased risk of hearing impairment. Screening procedures have been developed to supplement the high risk registry. These have included behavioural inventories, audiometric testing in addition to various neurological measures and devices. Other methods of detection have included the use of developmental screens which service to monitor the child's attainment of developmental milestones in the areas of fine and gross motor skills, language and speech, social and emotional development.

Related Skills.

Since most health units do not employ audiologists for diagnostic testing or for supervision of screening programs, those health units in Alberta specifically, like elsewhere, experience significant problems identifying a potential hearing impairment given their limitations in financial and manpower resources. Identification of expanded high risk criteria are suggested by recent literature can perhaps aid in solving or at least reducing this problem. Routinely the health units administer a developmental screening test to each child at regular intervals up to kindergarten entrance. One frequently utilized is the Denver Developmental Screening Test. The Denver considers four general skill areas, including language, social, fine and gross motor skills. Can these data provide any additional correlational data indicative of possible

hearing impairment? The literature in this area is hopeful, if inconsistent in findings. Furthermore, the vast majority of research in this area has been done involving sensorineural losses, rather than conductive. Therefore, unless otherwise indicated, the following studies were based on sensorineural impairments.

Motor Skills

As early as 1960, Myklebust, Boyd (1967) and later Lindsey and O'Neal (1976) observed through their respective research efforts that deaf children are inferior to normal hearing children on test items which measure equilibrium (static and dynamic) and locomotor coordination (Brunt and Broadhead, 1982). The latter researchers found, in addition, that on visual-motor control skills, the performance of deaf children were significantly inferior at the 8 - 10 year age levels on static balance performance. They also found a maturational effect on the locomotor coordination test items indicating increasingly significant differences for hearing and deaf children at all age levels.

Perhaps one of the most exhaustive studies in this area was carried out by Zausmer, (1971). Zausmer considered 11 motor skill areas of 43 deaf children, all between the age of 3 - 4 1/2 years. The motor skills tested included; muscle strength, flexibility, muscle tone, balance, gross motor skills, fine motor skills, ball skills, gestural imitation, character of movement, self care and general adaptive behaviour. Her results indicated that for those deaf youngsters who were high scorers on accompanying social skills

tests, optimal use of intellectual capacity, motivation and previous training was used to compensate for low motor scores. Moreover, she found that for those children who had lower overall motor scores, it was a function of muscle strength. In further analysis, Zausmer revealed a very interesting factor. Those children who achieved highest overall scores were those born of mothers who contracted rubella after the eighth week of pregnancy, thus revealing a positive relationship between gestational age of infection and degree of deficit. The most significant trait of these children was difficulty with equilibrium. The researcher suggested that perhaps damage to the organ of Corti is to blame for this, and this organ was most frequently damaged when mothers contracted rubella between the fifth and eighth week of pregnancy. In conclusion then, Zausmer cited a significant relationship between contraction of maternal rubella within the first eight weeks of pregnancy and equilibrium deficits. She hypothesized that this deficit increases with the degree of hearing impairment.

Geddes (1978) found a relationship between the equilibrium skills and the presence of a hearing loss due to meningitis, rather than rubella.

A study in 1983 by Wiegersma and VanDer Velde considered the notion that Zausmer (1971) put forth, that the degree of hearing impairment determines the degree of equilibrium problems or deficits exhibited by deaf children. They were unable, however, to come up with any reliable findings. Instead, they found that 6 - 10 year old

healthy deaf children were clearly inferior in general dynamic coordination when judged against a comparable group of normal hearing controls. Secondly, they felt that differences may be due to processes underlying execution of the motor movement. Some of the underlying processes they considered included:

1. Organic Factors
   a) vestibular deficits
   b) neurological defects
2. Sensory deprivation
3. Verbal deprivation
4. Emotional factors
   a) poor self concept
   b) lack of confidence

In conclusion, this study stated the need for further research as according to these researchers, the motor deficits of deaf children are clearly present, however, the reason for them is unclear. They did not find any significant relationship between degree of impairment of hearing and deficits in equilibrium skills. Carlson (1971) generated similar findings.

Finally, Butterfield (1986) considered hearing impaired children from 3 to 14 years of age. He concluded as a result of his research that gross motor skills performance was not related to etiology of deafness as Zausmer (1971) and Geddes (1978) both hypothesized.

In conclusion then, it would appear that sensorineural hearing impaired and deaf children do typically show some retardation of motor skills, though the reason for this is unclear. The question

then, which comes to mind is whether results of motor performance generated by the Denver Developmental Screening Tests are related in any way to performance on kindergarten hearing screening tests?

Language Skills

The relationship between hearing impairment and language and/or speech skills is more clearly documented than is any relationship to motor skills.

With respect to language acquisition, the majority of research has led to conclusions which claim that the language of hearing impaired children is indeed deviant (Schirmer, 1985). Since the institution of PL 94-142 in the U.S., a renewed surge of interest has evolved in this area, with remediation as its specific focus. One such study by Schirmer (1985) considered the syntactic, semantic and pragmatic usage of language in twenty 3 to 5 year old hearing impaired children. For her analysis, Schirmer utilized Brown's five stages of language acquisition, Bloom and Lahey's plan for language development goals, Lee's developmental sentence analysis and Halliday's phases of functional language. Based on the results of this study, Schirmer concluded that hearing impaired children do not exhibit deviant language, as it was not different from that of normally developing children. A superior description according to Schirmer, would be to consider their language delayed, not deviant.

This view is supported by a more recent study carried out by Bracken and Cato (1986), in which language in relation to concept

development was examined. Thirty-four preschool and primary hearing impaired children were tested using the Boehm Test of Basic Concepts. These researchers found the hearing impaired children to be approximately two standard deviations below the performance of a matched control group of hearing children. Thus, they stated that the hearing impaired children performed conceptually at a level commensurate with mild retardation. They attributed this to a delay in language in general and cited Meadows (1968) who stated that the average four year old has a vocabulary of 2000 to 3000 words, while the severely hearing impaired child has a vocabulary of less and 25 words. If this is indeed the case, it is reasonable to assume that even a mild to moderate loss would result in a reduced vocabulary size.

The literature is full of additional studies relating language delay and hearing impairment (Gerken, 1979; Goetzinger, 1962; Davis, 1974). ISO (International Standards Organization) recognizes the relationship in their classification of hearing loss (Skinner and Shelton, 1978). For example, according to their classification, a slight loss (25 - 40 dB threshold in better ear), results in slower language and speech development than what would be normally expected. A mild loss (41 - 55 dB) however, results in a significant delay of speech and language. Clearly, according to this taxonomy, the greater the hearing impairment, the greater the delay in speech and language (Skinner and Shelton, 1978). Perhaps the nature of this language delay associated with hearing impairment is best described

by Larson and Miller (1982) who state that linguistic development and vocabulary growth are life long processes and depend upon repeated exposures to words before they become part of the child's repertoire. These repeated exposures may not always be available to a hearing impaired child. Clearly, these studies refer to children who possess sensorineural hearing impairments. What of those possessing conductive hearing losses? Katz (1978), conducted a study which results in the following conclusions. Katz stated that a conductive hearing loss:

1. can interfere with the acquisition of good auditory perceptual skills,
2. can adversely influence language development,
3. can increase the likelihood of having a significant learning disability, and
4. can lead to aberrant results on auditory tests that might be mistaken for signs of gross retrocochlear or brain lesions.

Katz (1978) further stated that a conductive hearing loss can create a situation of sensory, in this case auditory, deprivation. The effect of the deprivation in Katz's opinion is far reaching and depends on numerous factors. Included in these factors are the age of onset, the duration and degree of the loss, whether the loss is unilateral or bilateral, constant or variable, and the testing procedures. He continued that the greater the hearing loss and the longer the period of deprivation, the more extreme the retrocochlear signs. Disruption in auditory perception and language functions,

both presumed to be cerebral functions are associated with hearing loss, especially unilateral problems with an early onset age. Katz found also, that even after the blockage has been removed, abnormal auditory function may still persist.

In a subsequent article, Katz (1985) expanded on his concept of the deprivation experienced by children with conductive losses. Katz divided the effects into three components. The first of these he referred to as the plug-in-the-ear effects. He stated that this refers to reduction in speech information which has subsequent adverse influence on both hearing and comprehension. An identifying characteristic of this problem is that the communication problem lasts only as long as the hearing loss. The only remaining problem, according to Katz would be that information was lost, distorted and misinterpreted during the period for which the loss was present. Katz went on to discuss the restriction effect, in which adults with history of conductive losses were later found, using auditory brainstem response testing, to exhibit damage resembling that of a retrocochlear nature, thus concluding that conductive losses can influence the functioning of the retrocochlear system.

Finally, Katz (1985) spoke of early auditory deprivation effects which he felt could be expected to remain long after the hearing loss is gone.

Katz is certainly not without opposition on this subject. For example, Kessler and Randolph (1979) studied 29 third grade students with normal hearing, but with a history of middle ear pathology

before three years of age. This group was then compared to a group of 19 third grade students with normal hearing and no history of middle ear pathology. These 38 children were given a battery of nine tests designed to measure auditory ability. Their results indicated that on 4/9 tests, the group with history of a pathology scored significantly below the controls. On the remaining five tests, nowever, no significant differences were found.

Furthermore, in 1979 a review of the literature on the effects of conductive losses on childrens' language and scholastic skills was completed by Rapin. She criticized the validity of studies in the area on several points. Firstly, she cited the lack of longitudinal studies on the effects of conductive hearing losses on the language development of preschool children. Secondly, she stated that the degree of loss necessary for deleterious effects being manifested is left unanswered. The length of time for which a conductive loss must persist before any adverse effects develop is also questionable. Finally, Rapin stated that many of the studies used to support the view that detrimental effects result, are invalid due to cultural differences. Frequently, these studies have utilized Eskimo or Aboriginal populations, while using tests with Western norms.

From this discussion, it can be seen that the literature is clearly divided on the subject. Many questions remain unanswered in relation to conductive losses. It is evident that a direct causal relationship with sensorineural hearing impairment exists. Not only is vocabulary frequently reduced when compared to age norms, but

general language ability is frequently delayed in the presence of a hearing impairment. Moreover, some very specific speech characteristics exist, including inappropriate pitch, volume, and melody in addition to articulation errors and in more severe losses, nasality. Similar to the situation discussed in relation to motor skills, could not the language and speech characteristics be used to assist in detecting a hearing loss? There are after all, specific language and speech results available through the routine use of such tools as the Denver Developmental Screening Test. This test could be supplemented by parental report and informal observation by an informed nurse, utilizing previously described techniques. These data, however, are frequently not collected, is highly unreliable and is seldom analyzed if few additional problems are noted.

Social Skills

The manner in which a hearing impairment early in life affects social skill development could be considered inconclusive at best. The majority of the literature in this area deals with sensorineural hearing impairment or deaf individuals of at least adolescence. Very little research has been completed on the social skill development of hearing impaired children of preschool age. Larson and Miller (1982) state that this is due to the fact that during the early years of life, hearing impaired children perform on par with hearing children in the areas of self-help, adaptive behaviour, social and emotional behaviour. These researchers feel that it is not until at least

adolescence that the social deficits are manifested resulting in withdrawal and eventually, isolation. If this is the case, it would be reasonable to hypothesize that a conductive loss, of short or fluctuating frequency and duration, would result in few adverse effects.

One study which did consider preschool aged sensorineural hearing impaired subjects was carried out in 1981 by Vandell and George. These researchers considered dyads of hearing impaired and hearing children and found that the number and length of interactions observed were greater in like (deaf-deaf or hearing-hearing) dyads than in mixed dyads. Furthermore, in both types of dyads, the hearing impaired children were observed to make frequent and persistent social initiations. These initiations were more likely to be actively refused by the hearing child rather than by a second hearing impaired child. The researchers also noted many instances in which social initiations were made toward the hearing impaired child with that child being unable to receive them. Examples of this included gestures or vocalizations behind the hearing impaired child's back. Thus, they were unable to respond and participate in many potential social interactions. The authors concluded that delayed or disordered communication skills themselves result in reduced interactions which in turn delay the development of social skills.

A handful of additional studies exist, which consider the nature of the social interaction between preschool hearing impaired children

and their mothers. Schlesinger and Meadow (1971) found that in comparison with mothers of young hearing children, mothers of young hearing impaired and deaf children were consistently rated as more controlling, more intrusive, more didactic, less flexible, less approving and less encouraging. Goss (1970) found similar results, with 40% of the behaviour of mothers of hearing impaired children to be directing. All of these researchers agree that to a great extent, the opportunity of social interaction is reduced for the hearing impaired child as a result of the impairment. This lack of opportunity only serves to add to the delay in both communication and social skills.

One study which appears successful in its identification of pertinent social skills of the hearing impaired child was completed in 1983 by Kathryn Meadow. In an attempt to compile a useful and reliable instrument to assess social and emotional behaviours of hearing impaired preschoolers, Meadow identified four general types of behaviour which hearing impaired preschoolers are reported to most often display some aberration or difficulty. Each behaviour within the four major types is weighed in terms of its significance. The first area identified by Meadow (1983) was Sociable, Communicative Behaviours. Included in this category were behaviours such as:

- shows interest/pride in activities,
- forms warm attachments with peers,
- unsuccessful in efforts to get approval from peers,
- exhibits "strange" behaviour,
- has age appropriate attention span,

- isolated,
- withdrawn,
- avoids eye contact,
- communicates using various means,
- happy,
- curious,
- creative,
- displays negative attitude toward interaction,
- lacks appropriate range of emotional responses.

A second area identified by Meadow (1983) included Impulsive, Dominating Behaviours. Within this category were behaviours such as:

- follow instructions,
- overly aggressive,
- acceptable emotional responses,
- accepts delay of gratification,
- engages in destructive behaviours,
- teases other children,
- persists in silly, clowning behaviours,
- unable to accept criticism,
- cries due to frustration stemming from inability to master tasks,
- demands attention,
- impulsive,
- denies own misbehaviour,
- turn taking present.

In the third category, Developmental Lags, Meadow (1983) identified:

- wet pants,
- awkward or clumsy with tools,
- feeds self appropriately,
- communicates toileting needs,
- engages in self-abusive behaviour (head banging, biting).

Finally, Anxious, Compulsive Behaviours are considered in the fourth category developed by Meadow (1983). Examples of behaviours identified in this area are:

- overly fearful,
- ritualistic,
- overly concerned with cleanliness,
- shows preoccupation with insignificant details,
- uses hurts, etc., to gain attention,
- anxious, worrisome.

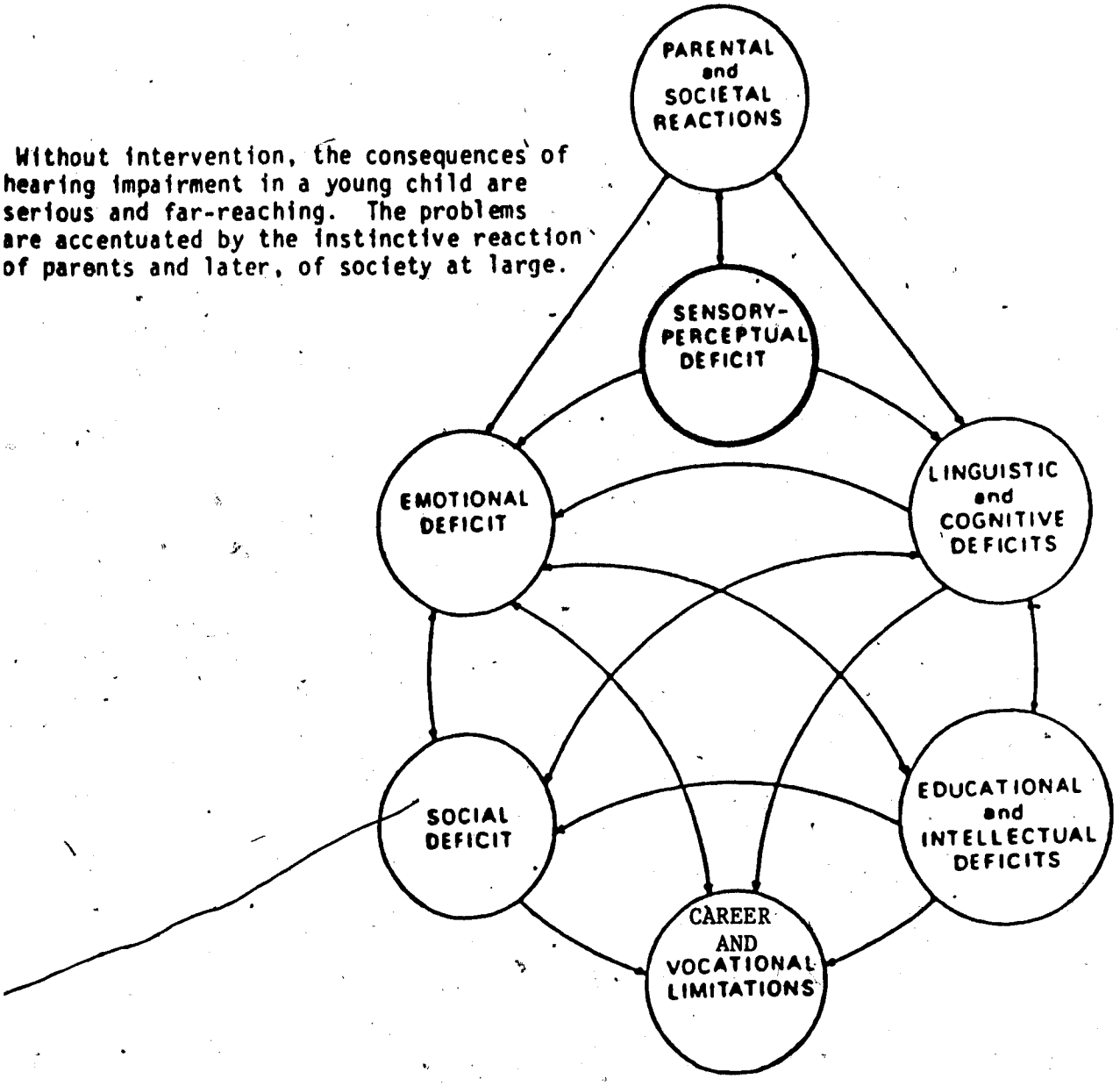
Clearly then, from the last study completed by Meadow, there exist numerous behaviours with which sensorineural hearing impaired preschoolers demonstrate difficulty. Figure 6 graphically depicts these problems well. Many of these are common to hearing children as well, but less often and to a lesser degree. It remains unclear whether these behaviours occur any more frequently in children with conductive losses than they do in normal hearing children. The question of interest in this study is whether there are any items on the social scale of the Denver Developmental Screening Test which would tap some of these behaviours that hearing impaired children are

frequently deficient. Upon close examination of the DDST, it can be seen that many items included do indeed test the very things which Meadow feels are particularly common in hearing impaired children (Figure 6).

INSERT FIGURE 6 ABOUT HERE

FIGURE 6 A Model of Deficits

Without intervention, the consequences of hearing impairment in a young child are serious and far-reaching. The problems are accentuated by the instinctive reaction of parents and later, of society at large.



Adapted from Hearing Impairments in Young Children (p. 6), by A. Boothroyd, 1984, U.S.A.: Prentice-Hall Incorporated. Copyright 1984 by Prentice-Hall Inc.

CHAPTER III

RATIONALE SECTION

The problems encountered in hearing screening of young children are numerous. Firstly, much of the literature states that pure-tone audiometric screening cannot be completed reliably before the age of three years in the absence of a well equipped audiological facility employing well trained audiologists. The devices which do exist and are reliable and effective are extremely expensive, likely well beyond the expenditure limit of most local health clinics.

Secondly, birth history alone is not a reliable predictor of hearing impairment. Not only are a large number of childhood hearing impairments due to unknown causes, mothers contracting rubella, syphilis, and other potentially harmful illnesses are not always accurate in reporting these experiences.

Thirdly, it is routine in most Alberta health units to collect birth history, birth injury, reports, Denver results, in addition to information pertaining to family history. The literature tends to deal with these sources of information in isolation. There is no clear evidence that these various sources of information have ever been analyzed in terms of their relation to one another. That is, is the overall health chart of a child who passed the pure-tone audiometric screening different from that of a child who failed the screening? One might hypothesize, for example, that a child prone to either intermittent conductive losses or a sensorineural loss

would more frequently have a "failed" language scale on the Denver. Given financial and manpower limitations facing all public health facilities today, it seems timely to consider this as a possible way to improve detection of hearing impairment without escalating costs.

Research Questions

Based on this literature review, the following questions emerge as critical in improving the detection of hearing impairment in preschool children.

1. To what degree is data collected on physician's notes, including significant historical and perinatal factors, related to pure-tone and impedance test results obtained through routine kindergarten screening?
2. To what degree is performance on each of the four Denver Developmental Screening Test scales related to passed or failed results on audiometric testing in kindergarten?
   - personal-social,
   - fine motor-adaptive,
   - language,
   - gross motor.

a) Does the age at which the item failure of the Denver significantly relate to audiometric results in kindergarten?

3. Do any parental characteristics including the age and occupation of the mother, father's occupation, and child's birth order correlate with performance on audiometric testing in kindergarten?

a) Is socioeconomic status related to audiometric test performance?

4. Following a first failure on audiometric testing in kindergarten, what proportion of those underwent subsequent intervention and/or testing?

a) How many of those failed subsequent testing?

5. Can a predictive model of possible hearing impairment, indicated by failure on audiometric testing in kindergarten be generated?

a) Through statistical analysis, do any of the aforementioned variables and/or test items cluster in relation to audiometric results?

b) Can those factors be weighed in such a way to generate a linear arithmetic equation which more accurately predicts the presence of a hearing impairment?

Once these questions can be satisfactorily addressed, perhaps a linear model of prediction can be generated which would be of a more reliable predictive value than those methods presently in existence in the health units.

Definitions

For the purposes of this study, the following operational definitions have been outlined.

1. Birth History

Any notation in the health chart involving:

a) prenatal maternal illness/conditions,

b) paternal health conditions prior to or at the time of conception,

c) any childhood disease contracted for 0 - 4 1/2 years of age,

d) includes any of the following:

Familial History of Convulsions,

Familial Diabetes/Cancer/Schizophrenia,

Maternal Rubella,

Maternal Red Measles,

Asthma,

Chicken Pox,

Ear Infection,

Allergies,

Cerebral Palsy,

Scarlet Fever,

Respiratory Difficulties,

Jaundice,

Epilepsy,

Mumps,

Tuberculosis,

Hearing Impairment (Familial),

Speech Impairment,

Language Delay,

Vision Difficulties,

Pneumonia,

Tonsillitis.

2. Birth Injury

Any notation in the health chart indicating deviations from what is medically considered to be a "normal birth". Included are the following:

Caesarean Section,

Assisted Breech,

Tube Feeding at Birth,

Induced Labour,

Forceps Delivery.

Also included in Birth Injury are conditions noted at birth indicating congenital abnormalities, including:

Cleft Palate,

Congenital Hypospadius,

Congenital Ear Malformation,

Congenital Heart Problems,

Congenital Physical Malformation,

Fetal Alcohol Syndrome,

Blindness,

PKU,

Hypothyroidism.

3. Failure on Audiometric Screen

Any instance of a failed response at the kindergarten screen in either the pure-tone air conduction test (in compliance with Canada Health and Welfare Standards, 1982) and/or failure of the impedance test. One failed trial on either test constitutes a failure on the screen.

4. Failure on Denver Items

Any failed, questionable or repeated item recorded on the Denver, based on the judgement of the administering nurse.

CHAPTER IV

METHODS SECTION

This study involved the post-hoc analysis of data collected and present in the records of children born between 1976 and 1979 in the Leduc-Strathcona Health District. In Alberta, the Leduc-Strathcona unit like many other health units, conducts well baby clinics to provide inoculations, parental support services, in addition to routine developmental testing. These services are available to children and parents of children from birth to kindergarten.

The developmental testing specifically, is undertaken at any of 3, 6, 12, 18 and 54 months of age. At these times, the appropriate medical services are provided and developmental testing completed. The Revised Denver Developmental Screening Test is generally administered, and the results placed in the child's health record. These results include information indicating which items were failed (delayed) and items which required retesting at a later date. Areas screened through the use of this test include personal-social, fine motor-adaptive, language, and gross motor. A gross judgement of hearing acuity is generated through observations of performance on particular Denver test items. These include:

1. localization response to bell at 1 - 3 months of age,
2. turns to voice at 5 to 9 months of age,
3. imitates speech sounds at 7 - 11 months.

In addition to the results of developmental testing, any significant birth complications, family medical history, preschool health problems, and results of pure-tone air conducted audiometric screening and impedance testing completed in kindergarten are present in the file of the children followed by the health unit.

This study analyzed these data, following from birth to kindergarten for two groups of children. Group 1 included those children who at completion of testing in kindergarten were identified as failing either the hearing and/or impedance test, in one or both ears. For analysis purposes, these will be subdivided into groups similar to those set out by the American Speech and Hearing Association (1985), separating those who failed bilaterally versus those with a unilateral failure. In addition, for the purposes of this study, performance on impedance testing will be considered in relation to the pure-tone performance. Therefore, the following groups will result, however, only the first will be used in an attempt to generate a model of prediction.

1. Bilateral failure on pure-tone testing; failed impedance
2. Bilateral failure on pure-tone testing; passed impedance
3. Unilateral failure on pure-tone testing; failed impedance
4. Unilateral failure on pure-tone testing; passed impedance

Group 2 included children who had been followed for the same period of time, but who at no time were identified as demonstrating

any hearing impairment (i.e., did not fail audiometric or impedance testing). Both groups consisted of approximately 200 children, all of whom were born between 1976 - 1979. The charts of all children born during these three years were divided into two groups - possible impairment and normal. From those two groups, 200 were randomly chosen from each, therefore, degree and impairment characteristics were randomized. A total randomization of subjects was not possible, as in any given year, with an average of 10,000 live births, only 5% are detected as manifesting a hearing impairment. This number in reality is even lower due to attrition, therefore, the number of subjects satisfying the criteria of this study was considerably less than 500 for any given year.

Once the two groups of subject's records had been separated, the following data was extracted from each.

1. Birthweight
2. Gestation age
3. Birth Injury
4. Medical history (familial) - history of hearing impairment, middle ear infections if documents.

These four variables appear frequently as at risk factors for hearing impairment (Health and Welfare Canada Task Force on Childhood Hearing Impairment, 1984).

In addition, several other data were e[illegible]rom the health chart; the hypothesis being that they may be correlated with a failed pure-tone screen and possibly a hearing impairment. The latter cannot be established within this immediate study.

1. Failed Denver Developmental Screening Test items at each screening.
2. Mother's age at time of child's birth.
3. Mother's occupation.
4. Father's occupation.

The latter two were extracted to establish socioeconomic levels to be viewed in relation to follow-up practices.

Extracted as the independent variables for this study were:

1. Results of pure-tone audiometric screening in kindergarten.
2. Results of impedance testing in kindergarten.

At the time of data collection, all data were coded numerically to ensure confidentiality. All data were collected from the Sherwood Park, Alberta Sub-Office.

In this study, several concerns must be noted. As stated in the review of the literature, pure-tone hearing screening tests can be methodologically problematic. These methodological problems are also present in this study, as they relate to the pure-tone testing. For example, the pure-tone screening in this study was generally completed in a school setting, thus ambient room noise may have been a factor. Secondly, portable audiometers were used, thus calibration, and overall accuracy of the instrument have been assumed to be adequate, however, this cannot be validated. Thirdly, the screening itself was carried out by public health nurses rather than by an audiologist as suggested in the literature. These nurses were trained in executing the screen, however, not trained as extensively

as would be an audiologist, thus less able to allow "clinical judgement" enter into the testing situation.

For these preceding reasons, it must be noted that any results obtained through this study must be interpreted with some caution, since the same limitations emerge in this study as those noted in the literature on pure-tone screening.

Moreover, Denver performance reports must also be interpreted with equal caution, as there is great variance in application and reporting. Each nurse is required to make a judgement on performance thus, the Denver results in the health chart are dependent upon the accuracy of the various nurses judgement and recording.

CHAPTER V

RESULTS AND DISCUSSIONS

All data collected were numerically coded for computer analysis. A total of 50 variables existed for each subject. The subjects were divided into the following type groups prior to analysis.

Type 1

Individuals failing both pure-tone audiometric screening and impedance testing bilaterally.

Type 2

Individuals passing both pure-tone audiometric screening and impedance testing bilaterally.

Type 3

Individuals failing both pure-tone audiometric screening and impedance testing, and also failing a second follow-up testing of these approximately two weeks later.

Type 4

Individuals failing pure-tone audiometric screening and impedance testing, and passing a second follow-up testing.

The total distribution of subjects was:

Type 1: n = 62

Type 2: n = 234

Type 3: n = 9 (later extracted from Type 1)

Type 4: n = 31 (later extracted from Type 1)

The remaining subjects not accounted for in this distribution scheme are individuals with random failures of the audiometric

screen. For example, any one instance of failure on either pure-tone or impedance testing was not considered to be valid enough to warrant inclusion in a group. Also, one failed instance on the pure-tone screen plus a failed impedance in the opposite ear, were excluded for similar reasons. Finally, since this is not a comprehensive study, unilateral failures were excluded and therefore, not analyzed beyond the point of determining whether or not they differed from the normal group across any of the variables. In all cases they closely resembled the normal group.

Of initial interest in this study was the comparison of Type 1 and Type 2, those who completely failed the first screen regardless of results on follow-up testing, and those who passed the initial screen completely.

The aforementioned groups were compared in terms of prenatal or perinatal factors including birth injury, birth history, and gestational age. With respect to birth injury, Types 1 and 2 were compared utilizing a chi square analysis. It was revealed that 21% of those in Type 2 were reported to have experienced a birth injury. This difference was not found to be significant as analyzed by the chi square calculation, nor was it found to be significant at the .050 level using a Scheffe Procedure.

A similar analysis was completed for the history variable. Type 1 was again compared to Type 2. Type 1 had a proportion of 82%

(51/62) of subjects being recorded as having, or a member of the family having some history of a medical abnormality, while in Type 2, 65% (153/234) had a similar history. Using both a chi square calculation and a Scheffe Procedure, this difference was found to be significant. There were, moreover, some interesting qualitative differences. Of Type 1 subjects, 32% were recorded as having a past history of middle ear infection. Type 2 on the other hand was found to have middle ear infection documented in only 11% of cases. Often related to this was the presence of allergies. In Type 1, the proportion of individuals recorded as having allergy problems was approximately 15% compared to 8.5% in the passing group, Type 2.

Also included in the health chart of each child was the gestational age. Types 1 and 2 were compared and no significant differences were noted using an ANOVA. A chi square calculation was significant as ($\chi^2 = 3.74$ $\underline{p} < .5$, $df = 4$) indicating that a greater proportion of children who failed the hearing screen, Type 1, had a gestational age of 35 weeks or less with the actual proportion being 6.3%, than did Type 2 in which only 2.6% were of a gestational age of 35 weeks or less.

Maternal age was also a factor for which data was collected. The age of the mother at the time of birth was then analyzed in relation to audiometric screening performance. The ages of the mothers were grouped in the following manner:

1 = 16 years and younger,

2 = 17 - 20 years,

3 = 21 - 30 years,

4 = 31 - 40 years,

5 = 40+ years.

Again, both a chi square calculation and an ANOVA were completed on the data with neither analysis revealing significant differences between groups. Type 1 mothers were more often of age 16 or younger (30%) than were Type 2 mothers (18%), though this difference, as previously stated was not found to be significant.

To answer the question whether or not socioeconomic status is at all related to audiometric screening performance, Blishen Occupational Class Scale (1951) was utilized. The Blishen Scale ranked occupations and grouped them according to combined standard scores for income and years of schooling. Blishen utilized Canada Census statistics in 1951 to construct this scale (Blishen, 1964). The resulting product consisted of seven "classes" of society, with 1 being of the highest income and education level, and 7 being the lowest. Thus, the fathers in this study were grouped in accordance with the classes outlined by Blishen. No significant differences were noted between Type groups either with chi square or analysis of variance. In both groups, the greatest proportion of fathers fell into Class 5, followed by Class 2. The same procedure was then applied to mothers occupation. Again, no significant differences between Type groups were noted, with the greatest proportion of all

mothers falling into Class 7 and 4 as outlined by Blishen. These data will be discussed further in relation to tendency to attend follow-up testing provided following a failed audiometric pure-tone screening.

A factor which was considered in addition to the aforementioned parental characteristics, was that of birth order. Once again, no significant differences were revealed utilizing chi square and analysis of variance procedures. In fact, the only trend which could be identified in these data was a comparably higher occurrence of pure-tone audiometric screen failure in second born children. For example, 31% of the passing group, Type 2, were second born children, compared to 45% of Type 1.

The next factor to be considered in relation to performance on the pure-tone audiometric screening was performance on the four scales of the Denver Developmental Screening Test. The Denver, as previously stated, consists of four performance scales; personal social, fine motor-adaptive, gross motor, and language. In this study, results indicating pass/fail performance on the scales were collected on three administrations of the test, per subject. Results of the Denver administration which typically accompanies the pure-tone audiometric screen were collected, in addition to results on the two administrations of the test immediately preceding the audiometric screen administration.

The personal-social scale was analyzed using an ANOVA, with no significant differences between subject Types being revealed. This

was corroborated by an insignificant chi square analysis. This was true for all three administrations of the scale.

The fine motor-adaptive scale was then analyzed using the same statistical calculations. The two Type groups were not considered significantly different in their performance on this scale of the Denver.

The gross motor scale of the Denver revealed no significant differences between the two Type groups, using either analysis of variance or chi square analyses.

The final scale, that of language, is the one which any researcher would expect to be most closely related to performance on a pure-tone audiometric screening. An ANOVA performed on these data revealed significant differences in performance on the second administration of the language scale on the Denver Developmental Screening Test. Using 0 = fail and 1 = pass, Type 2 subjects enjoyed a mean of .9725 while Type 1 subjects mean was .9850. Though the means themselves provide little information, they would indicate that Type 1 individuals were more prone to failure on the language scale than were Type 2 individuals.

Finally, in an attempt to capsulize performance on audiometric testing in relation to performance on the Denver, each subject was coded according to whether they failed any item on the last Denver screening which was administered; that being the one administered at the same age as the pure-tone audiometric screen. No statistical differences were revealed by either chi square or analysis of variance procedures.

Though not of primary concern in this study, birthweight was considered. Type 2 individuals differed significantly from Type 1. Utilizing the three point scale for birthweight, with 1 = less than 1500 grams (3 1/2 lbs.), 2 = 3.6 lbs. to 7.5 lbs., and 3 = 7.6 lbs. and greater, the mean of Type 2 children was 2.89 while Type 1 was 2.67. This would indicate that more children who passed the pure-tone audiometric screen were heavier babies at birth when compared to the failing group. In terms of actual proportions, 5.12% of Type 2 and 16% of Type 1 subjects fell into the low birthweight categor

Type 2 individuals also differed significantly from Type 1 individuals in relation to mothers' age. On the average, using the coding system 1 = 16 and below, 2 = 17 - 20, 3 = 21 - 30, 4 = 31 - 40, 5 = 41+. Type 1 mothers mean was 2.4 indicating a population in their mid to late twenties, while Type 2 mothers mean was 2.77, revealing on the average, older mothers than were present in the other Type 1.

The only remaining variable to be considered was a vision screen which was completed on three occasions for each subject. No significant differences between groups were noted using an ANOVA and chi square analyses.

Thus far, Type 1 has been the "fail" group, however, this has been on the basis of the first screen only. Presumably, any mixed losses would fail the second follow-up screen as well. However, it is very possible that any individual with a conductive loss could pass the second follow-up screen.

Hence, for further analysis, Type 1 individuals were sub-divided into those who failed the second screen, and those who later passed the second screen. These were then compared to Type 2 subjects to see if any additional information could be extracted. For the analyses based on these groups, Type 2 will continue to represent the normal group, Type 3 will represent those who failed both the first screen and follow-up screening, and Type 4 will represent those individuals who failed initially, but later passed follow-up testing completely. As a result of this new grouping, pure sensorineural losses have been eliminated from further analysis, as a pure sensorineural loss would in all likelihood result in a passed impedance screen on the second administration. This sensorineural group would very likely have been identified prior to kindergarten entrance. Moreover, since public health units predominantly come in contact with middle ear problems, it was those cases which were of possible conductive or mixed natures which were chosen for further analysis.

Utilizing this new Type grouping, the presence of a birth injury was analyzed. Individuals in Type 3 were almost twice as likely to exhibit a birth injury notation on their health record than were Type 2 individuals. Surprisingly, Type 4 individuals had the lowest incidence of birth injury. The incidence rates were 44%, 27% and 13% respectively. These differences, however, were not considered significant through chi square or analyses of variance procedures. Even so, it is interesting to note that in Type 3, 30% of the birth

injury notations identified the injury as an assisted breech birth, while only 2.7% of Type 2 was recorded as breech births. In the initial Type 1, prior to this sub-division, the incidence of breech births was comparable to that level occurring in the normal population.

With respect to the history variable, no significant statistical differences were noted between Types 2, 3 and 4. There were, however, some interesting trends which could be identified. In relation to middle ear pathology, 11% of the initial Type 1 individuals had a history of middle ear pathology. In Type 3, this proportion was 29%. In Type 4, the proportion soared to 41%, indicating that those in this Type grouping may well be excellent candidates to be considered the one distinctive grouping in this study exhibiting conductive hearing impairments. Furthermore, the history of articulation difficulties was found to occur in 5% of those individuals in both Types 2 and 4, however, occurring in 14% of those in Type 3, suggesting that a more prolonged hearing impairment is necessary prior to any significant articulation problems developing. Interestingly, no subjects in either Types 3 or 4 were recorded as having any history of language problems, nor did any of those subjects have familial history of hearing impairment.

From these data it is clear that quantitatively, few differences were considered significant between the new subject Types in terms of injury and historical variables. It is evident, however, that qualitative differences exist, in that a greater proportion of Type 3

individuals were assisted breech births. Furthermore, the existence of a history of middle ear infection and allergies occurred in greater proportion in the two failing Types, 3 and 4. Articulation disorders appeared in a greater proportion in Type 3 subjects, suggesting a time factor for which a hearing impairment must exist prior to any discernable articulation problems being noted.

Another factor which failed to be statistically significant as mothers' age, however, once again a trend can be seen. As previously stated, 18% of Type 2 mothers were of 16 years of age or younger. It is interesting to note that this proportion increased to 22% in the Type 3 and 32% in the Type 4 mothers with the mean of both Types being approximately 25 years.

Other variables which remained insignificant statistically were both maternal and paternal occupation and gestational age. No observable trends were identified.

The next set of variables which were considered using this new sub-division of Type groups was performance on the various Denver scales. Performance on the four scales across the three Type groups can be seen in Tables 3 through 7.

INSERT TABLE 3 ABOUT HERE

TABLE 3

Percentage of Items Failed on Personal-Social Scale

	Personal-Social 1	Personal-Social 2	Personal-Social 3
Type 2	23%	1.6%	5.8%
Type 3	11%	14.2%	0%
Type 4	6.8%	4.5%	0%

From Table 3, it can be seen that Type 3 individuals had higher proportions of failure on the personal-social items than did the other two groups. It is also important to note that [illegible] Types 3 or 4 showed failure on any personal-social [illegible] the third administration of the screen, the one complete[illegible] same time as the pure-tone audiometric s[illegible]

On the gross motor [illegible]gnificant difference was revealed by both chi square and a[illegible]is of variance procedures. On the second administration of the scale, Type 3 individuals were found to differ significantly from both Type 2 and 4. This was significant at the .050 level using a Scheffe procedure. Neither of the other two administrations of the gross motor scale revealed any significant differences across Types (Table 4).

INSERT TABLE 4 ABOUT HERE

As was noted in relation to the personal-social scale, none of either Type [illegible] or Type 4 failed the scale at the time of the third administration. This too, was the case for the gross motor scale. Due to lacking information as to the specific items failed, it is impossible to make any firm conclusions. However, it is possible to hypothesize that since the vestibular system is frequently involved in middle ear pathology, it would be possible that items involving

TABLE 4

Percentage of Items Failed on Gross Motor Scale

	Gross Motor 1	Gross Motor 2	Gross Motor 3
Type 2	8.2%	5.[illegible]%	9.2%
Type 3	22%	37.5%	0%
Type 4	9.6%	9.5%	0%

balance would be adversely affected (Katz, 1985). The Denver scale includes several items which involve walking, standing, stooping and balance, which must be successfully completed in order for the child to pass the gross motor scale.

Table 5 depicts results of performance on the fine motor-adaptive scale. A significant difference was found across Type groups 2 and 3 on the second administration of the scale. Again, it is interesting to note that no members of either Type 3 or 4 failed any item on the third administration of the fine motor-adaptive scale. This is consistent with results obtained on the two previously discussed scales. The item predominantly failed on the second screen was that which required the child to draw a man with at least six body parts included.

INSERT TABLE 5 ABOUT HERE

The final scale to be analyzed was that of language. From Table 6, a striking difference on the second administration of the scale can be seen. Type 3 individuals differed significantly from the other two Type groups at the .050 level utilizing a Scheffe procedure. Unfortunately, due to missing data in the health chart, identification of any specific item failed cannot be made.

TABLE

Percentage of Failed Items on The Fine Motor-Adaptive Scale

	Fine Motor 1	Fine Motor 2	Fine Motor 3
Type 2	6.6%	3.8%	8.1%
Type 3	11%	25%	0%
Type 4	10.7%	5%	0%

It is again interesting to note that the third administration of the language scale did not result in any failures by individuals in either Type 3 or Type 4.

INSERT TABLE 6 ABOUT HERE

Of those variables remaining, specifically birthweight, the three vision screens and the overall Denver performance, no statistically significant differences emerged across Type groups.

Lastly, the rate of return for follow-up testing was of interest in this study. Of those individuals who failed at least one component of the pure-tone audiometric screen, 81% returned for a follow-up test. The individuals who returned, and those who did not, did not differ significantly in terms of socioeconomic status as established by the Blishen Scale (1951).

Several conclusions can be offered, based on the results of this study.

1. Birth injury was not found to be significantly related to performance on the kindergarten pure-tone audiometric and impedance tests.
2. The presence of any historical pathology was found to be significantly related to performance on the pure-tone and impedance tests, though middle ear pathology and allergies emerged most frequently, followed by breech births.

TABLE 6

Percentage of Items Failed on The Language Scale

	Language 1	Language 2	Language 3
Type 2	3.9%	2.7%	4.1%
Type 3	11%	25%	0%
Type 4	6.8%	4.7%	0%

3. Gestational age of 35 weeks or less was significantly related to failed audiometric and impedance testing. It did not differentiate those who later passed from those who failed.
4. Maternal age of Type 3 and 4 children was not found to be significantly related to pure-tone and impedance test performance, though mothers of children who failed the first screen tended to be younger than those of children who passed, as evidenced by the initial Types 1 and 2 analysis.
5. Socioeconomic status was not found to be significantly related to audiometric and impedance test performance.
6. Birth order was not significantly related to audiometric and impedance test performance.
7. Failure on the Denver Developmental Screening Test scales on the second administration (mean age: 41 months) was significantly related to audiometric and impedance test performance. Gross motor, fine motor-adaptive and language scales were statistically significant.
8. In the majority of cases, subjects failing both an initial pure-tone and impedance test and also failing the follow-up test, differed more from the normal group than did those who initially failed but later passed follow-up testing. The latter group resembled the normal group more closely than it did the other initial failure group.
9. The proportion of subjects who returned for follow-up testing after an initial failure on the audiometric and impedance tests was 81%.

10. In summary, based on the comparison of Types 2, 3 and 4, five variables were revealed as being significantly related to pure-tone audiometric and impedance testing in kindergarten. These were:

a) Presence of some history of pathology, especially middle ear infection and allergies.

b) Failed gross motor scale on the Denver Developmental Screening Test on the second administration, with the mean age being 41 months or approximately 3 1/2 years of age.

c) Failed fine motor-adaptive scale on the Denver Developmental Screening Test second administration, with the Draw-a-Man task being the item failed.

d) Failed language scale on the Denver Developmental Screening Test on the second administration.

e) Gestational age of 35 weeks or less differentiated those who pass or fail initial screening only.

11. None of the subjects who failed the kindergarten audiometric screen failed any of the items on the language scale of the Denver relating to hearing, specifically localization to a bell, localization to a voice, or imitation of speech sounds.

12. Health units in Alberta would not increase screening efficiency by using additional non-audiometric data for predicting potential for hearing impairment.

The question which this study proposed to resolve was whether or not a predictive model could be generated, which would be

supplemental to the pure-tone audiometric screen in kindergarten. Perhaps, given the results generated in this study, the question should be one of whether it would be the most beneficial option available. Several factors must be considered.

Firstly, any model or equation would be based upon Type 3 individuals; those failing both initial and follow-up audiometric screening. Type 4 did not differ enough from the normal group to be discriminative in function. Even in the previous groupings, only the history variable, maternal age, birthweight and gestational age were seen as significant. The problem with using Type 3 individuals only to generate a prediction model or equation is twofold. Firstly, only nine subjects comprised the Type group. Secondly, it is impossible to determine which of those nine were conductive impairments and which were sensorineural. Those of sensorineural or mixed natures, and being of a significant degree, would in all likelihood have been identified through high risk registers and neonatal follow-up programs prior to kindergarten entrance. What about the children in Type 3 who are identified for the first time as having a conductive loss? By kindergarten, many cognitive, language, social and emotional skills are somewhat sophisticated. They have been developing for two years. To what degree these skills will be affected, will catch up, and will affect future scholastic success is controversial (Paradise & Rogers, 1985). It is only common sense however, to see the benefit in identifying any conductive loss as early in development as possible, rather than waiting for two years of development and growth to pass.

The next factors to be considered are those variables which were found to correlate with a failed audiometric and impedance screen. Both birth injury, and more specifically breech births, and gestational age are on the health chart from birth. History is updated as each visit to the clinic for immunizations is completed. Clearly though, as evidenced by the expanse of high risk registers, these are not sufficient in and of themselves to be used for prediction. They are included on current high risk registers along with many other related factors. Of interest, though, are those items on the Denver which were found to significantly relate to a failed audiometric and impedance screen. All three, gross motor, involving balance, fine motor-adaptive, specifically the Draw-a-Man with six parts item, and the language scale were ineffective at the kindergarten screen, in discriminating between normal and impaired hearing. It was at the second testing undertaken, at mean age 41 months, at which significant differences were observable. Note once again, that this was only found to be the case with Type 3 individuals.

The first question that arises in relation to these factors is why variables such as birthweight, mothers age and/or education were not found to be significantly related to performance on the audiometric screen for Types 3 and 4? Perhaps this is due to the fact that in this study at the most, nine subjects could have been individuals with mixed impairments. The high risk registers commonly utilized in health units and hospitals in Alberta include factors

found predictive of a sensorineural or mixed loss, rather than conductive. This could possibly explain the few number of variables found to be significantly related to performance on the audiometric and impedance screens. These high risk factors did not appear to be related to those who passed the second screen, presumably ruling out an impairment of a mixed or sensorineural nature.

What does this mean? Many variables have been considered. A few have turned out to be statistically significant. Could and moreover, should a prediction model or equation be generated given these results? This author's response to that question is no. Certainly, using linear regression analyses, an equation could be generated, but that, however, does not appear to be the most reasonable solution to a very large problem. Consider the following statements:

1. Differences in the areas of gross motor, fine motor and language begin to emerge as early as 3 1/2 years of age or 41 months, as evidenced by Denver performance.
2. After 3 1/2 years of age, no new predicting variables were identified.
3. Thompson and Weber (1974) were successful in teaching pure-tone play audiometry to 100% of children between the ages of 42 and 59 months of age. Many other authors concur with this claim.
4. If a 3 year old cannot be tested with play audiometry by a skilled clinician, it may indicate some other problem in addition to a hearing loss (Hodgson, 1985).
5. The majority of research points to ages below 4 1/2 as being critical for development of all aspects of the child.

6. Currently, no pure-tone audiometric screening is routinely performed on children in Alberta health units before the age of kindergarten entrance.

The obvious and very troublesome question which emerges is why the health units are waiting until kindergarten to do pure-tone testing. Experts in the field state it can be done reliably as early as 3 1/2 years. Performance on the Denver Developmental Screening Test begins to deviate from the norm at 3 1/2 years. Early interventionists state that the earlier identification can take place, the more effective remediation will be. Perhaps a more effective approach would be to routinely administer the Denver, the pure-tone audiometric screen and impedance test at 3 1/2 years as part of the total monitoring and follow-up of preschool children. Would this not at least partially solve some of the existing problems? It would certainly, identify those children with conductive impairments earlier, and when used in conjunction with Denver results, more frequently and reliably than in previous years. There would however, need to be some changes in current practice if this was to be effective. All researchers in the area of hearing screening emphasize the need for supervision and training of staff for such programs, by an audiologist. The cost effectiveness alone of such a program would surely provide the monetary resources to employ such a professional. Stricter adherence to procedure guidelines would have to become mandatory. To avert problems relating to availability of the children, could an audiometric/

impedance/developmental evaluation at 3 1/2 years not be made a prerequisite to kindergarten entrance?

Before such a recommendation can be made, the reliability of pure-tone audiometric air conduction screening and impedance screening must be considered more carefully.

In a recent study, Downs and Northern (1986) considered both pure-tone and impedance screens for use in schools, health clinics and physicians' offices. In their opinion, standard audiometric screening alone is not sufficient to detect pathological conditions in the ear. In fact, they stated that the audiometric screen may miss as many as 70% of the ears with pathologic findings. Thus, in their opinion, tympanometry, or impedance testing is essential to an effective hearing screening program. This view was corroborated by Jerger (1986) who stated that overwhelming evidence exists that indicates that tympanometry is an effective and necessary screening tool. Furthermore, Jerger stated that tympanometry is easy to use, acceptably inexpensive, effective in the short term and acceptable to the test population. Clearly, these researchers feel that pure-tone audiometric screening and impedance testing can be effective screening procedures for detecting a loss, particularly of a conductive nature. Downs and Northern (1986) stated in addition to these two techniques, that a screening test which samples language development can be a valuable supplement. In particular, these researchers city Early Language Milestone scale.

Also requiring a closer examination is the notion of testing a child using pure-tone audiometry at 3 1/2 years of age. As previously stated, Thompson and Weber (1974) realized excellent success in testing this age group. Moreover, Mencher (1975) stated as a resolution of the Nova Scotia Conference on the Early Identification of Hearing Loss, that periodic screening for hearing should be mandated beyond the age of two. Salvia and Ysseldyke (1985) on this topic stated that even though some younger children may fail a pure-tone audiometric test due to immaturity, that this can usually be accommodated for by the use of impedance testing.

Taking these two concerns into consideration, it seems as though screening the hearing of 3 1/2 year old children, using pure-tone audiometry, impedance testing and some short developmental screening instrument sensitive to language skills, is a reasonable recommendation to make. As evidenced by the results obtained through this study in terms of predictors of hearing impairment, none emerged after the age of 41 months. Deviations in Denver performance were evident at the 41 month level. The only remaining factors which were considered to possess predictive value were items already present in high risk registers. Therefore, it would appear that hearing screening programs in public health units around Alberta, would best improve their programs by beginning routine screening using pure-tone and impedance testing at 3 1/2 years of age, rather than postponing it to kindergarten. The indicators are present at 3 1/2, the literature agrees that children are testable at that age. Why wait a

year and a half, during which time language, cognitive and possibly pragmatic social skills could be hindered by a hearing impairment? Perhaps an answer to that question relates to availability of the children. Kindergarten ensures the availability of the children. Is it impossible, though, for health units to require a 3 1/2 year old screening for each child prior to kindergarten, without which the child cannot register for kindergarten? By the very fact that many screenings of children in this study were administered at a mean age of 41 months, it can be seen that many children routinely visit the clinic at that age regardless of any kindergarten entrance requirement. Rather than searching for additional predictor variables, it seems appropriate that earlier institution of routine hearing screening in health units would be an appropriate goal to strive for.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this study was to identify any variables present in health unit health charts, which possess any predictive value for future hearing screening failure. If so, could these variables be utilized to generate a model and/or equation of prediction, which could be used to supplement the pure-tone audiometric and impedance screen completed in kindergarten?

A total of 426 health charts were analyzed, half of those passing the pure-tone audiometric and impedance screens, half failing at least one trial of either the pure-tone audiometric and/or impedance screens. Data on a total of 50 variables were collected for each child born between 1976 and 1979. Using one-way analyses, each variable was considered in relation to performance on the pure-tone audiometric and impedance screens completed in kindergarten. Of prime interest to this study were those children who completely passed the tests on the first administration in comparison to those who completely failed pure-tone and impedance testing on the first administration. The latter group was later sub-divided on the basis of a complete pass or fail on the second, follow-up testing.

Of the variables considered, gestational age of less than 35 weeks, the presence of some history of pathology, specifically middle ear infection and allergies, assisted breech births, and failure on the gross motor, fine motor, and language scales on the Denver Developmental Screening Test were all variables which were found

to possess some predictive value. This value, however, was limited only to those failing an initial and follow-up screen. Those with an initial failure and subsequent pass, resembled the norm group, as did those with unilateral failures on either pure-tone or impedance testing. Given the results of this study, the following recommendations can be made:

1. Based on data currently available in health unit charts, the development of a predictive model or equation does not seem appropriate at this time, as few variables were found to be statistically significant, and furthermore, only apply to those individuals who completely failed both an initial and a follow-up pure-tone audiometric and impedance screens.
2. Pure-tone audiometric testing, impedance testing, and developmental testing should be routinely carried out beginning at age 3 1/2 years rather than at kindergarten entrance.
3. The audiometric and impedance screens should strictly follow established procedural guidelines and moreover, be under the supervision of a qualified audiologist.
4. Current screening programs should ensure financial resources sufficient to employ the appropriate professionals. When one considers the cost effectiveness of such a program in comparison to those currently in existence, the salary for an audiologist does not seem an unrealistic expenditure. Initially, one

audiologist per health district could train and supervise nurses or nursing aides in accordance with established procedural guidelines. The initial outlay would be great, but with time much money would be saved through reduced rescreening.

5. Performance on the pure-tone and impedance screen should be analyzed in relation to those factors which emerged as significant, namely:
   a) Gestational age of less than 35 weeks.
   b) Presence of history of pathology, specifically middle ear infection and allergies.
   c) Failure on gross motor scale of the Denver Developmental Screening Test, at approximately 41 months possibly indicating some general gross motor, coordination, and balance difficulties.
   d) Failure on the fine motor-adaptive scale of the Denver, with Draw-a-Man task causing difficulties.
   e) Failure on the language scale of the Denver.
6. Once again, caution should be exercised when interpreting the results of this study. Being of a historical nature, it is difficult to validate the variables of interest. A somewhat liberal level of significance (.05) was accepted in the analysis of the variables. Being an exploratory study these shortcomings are excusable. However, further study is needed in the area, examining these initially significant variables more vigorously. Not only should variance in testing procedure, location, and

criteria be controlled for, a higher level of significance in variable differences should be required.

In conclusion, this whole issue can be summarized in one sentence:

Why rely on a prediction model or equation when the skills in question can be, with adherence to procedural guidelines, be reliably and directly tested directly, as early as 3 1/2 years of age? Until such time that instruments such as Auditory Brainstem Responses (ABR) can be made available in all health units, a 3 1/2 year old screening of the aforementioned nature might prove to be a reasonable interim solution.

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