The Loudness Discomfort Level Test: Its Diagnostic Value in Rubella Deafness

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THE LOUDNESS DISCOMFORT LEVEL TEST:
IT'S DIAGNOSTIC VALUE IN RUBELLA DEAFNESS

BY

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Introduction and Rationale

The embryological development of the human body is a delicate and precise stage. This process of formation can be disturbed in a great number of ways (Christie, 1969). Ordinarily the growth of the fetus follows a nine month systematic pattern. Any disruption that occurs during these first nine months could cause permanent physical disability (Swann, 1944). It is known that rubella (German measles) can produce disorders in various physiological functions of the infant born to mothers who contracted the disease while pregnant. It was first discovered that congenital cataracts were a manifestation of rubella (Gregg, 1941). It is now well established that congenital heart disease, developmental defects of the eyes, impaired hearing, social maladjustment, low birth rate, purpura, bone changes and neurological impairments are among the abnormalities associated with maternal rubella (Christie, 1969).

Rubella is a viral infection known by its effects rather than by its composition. Acquired rubella is an insignificant ailment, causing much less inconvenience to the patients than the common cold. It can pass however from the pregnant woman, through the placenta to the embryo (Christie, 1969). This problem had been thought to occur primarily in only the first four months of pregnancy.
(Mann, 1944); but current research reveals that the virus may injure the fetus as late as the seventh month (Hardy et al., 1966 and Bordley et al., 1968).

It was previously believed that the increased susceptibility to infection during the first trimester of pregnancy was due to a lower concentration of properdin in the serum of pregnant women (Christie, 1969). It has been revealed that the length of time the child carries the virus is also significant (Bordley et al., 1968).

Rubella is noncytolytic which effects the reproductive capacity of the cell causing them to possibly die prematurely. The infected cells excrete the virus which in turn infects other cells (Ward et al., 1968). The cell disturbance may be related to the disruption of embryogenesis, producing anomalous organ development. The rudiments of the inner ear are becoming apparent during the first trimester of gestation. Since it is believed that the fetus is highly susceptible during this span of development, rubella has a damaging effect on the formation of the auditory mechanism. The most critical time during pregnancy is 2.1 months (Mann, 1944; Barr and Lundstrom, 1961), but an infection occurring from six weeks to three months may be detrimental (Murray, 1949). In a study by Jackson and Fisch (1958) of 57 children, ages three to five with history of maternal rubella during the first 18 weeks of gestation, 14 suffered from impaired
hearing. In other similar studies by Barr and Lundstrom (1961) and Sheridan (1964), 12 to 19 per cent of the affected children had impaired hearing.

Rubella rarely causes total deafness (Bordley et al., 1968). Sheridan (1964) and Barr and Lundstrom (1961) found thresholds poorer than 20 dB at frequencies of 500, 1000, and 2000 Hz in rubella children. Both studies showed approximately nine per cent severe bilateral losses of greater than 70 dB. The losses may be unilateral but more often are incomplete bilateral (Richards, 1964). Audiometric testing in rubella patients may be difficult since the problem is present at birth and therefore communication is often severely restricted (Richards, 1964). The consequences of this problem lead to the frequent misdiagnosis of aphasia, mental retardation, or "brain damage" (Hardy et al., 1966).

Effects of Rubella on the Auditory Mechanism

Once infection of the embryonic cell which are at the critical differentiation stage of organ development (organogenesis) occurs, severe damage to the developing organ may result (Ward et al., 1968). In the inner ear any part of the structure may be involved in the degenerative process (Christie, 1969). The characteristic damage is usually confined to the cochlear duct and saccule (Ward et al., 1968). The predominant changes are those of sacculocochlear degeneration category of Sheibe (Richards, 1964). In some
pathological findings a derangement and underdevelopment of the stria vasularis is found (Grey, 1959). In the cochlear ducts the volume of endolymph is significantly diminished causing the collapse of Reissner's membrane (Ward et al., 1968). There may be changes in the tectorial membrane causing it to become retracted from the organ of Corti and roll up into the inner sulcus or upon the limbus (Ward et al., 1968). The hair cells in the organ of Corti are usually absent or malformed (Richards, 1964). These findings result in the sensorineural loss that often occurs in maternal rubella. Because rubella happens at any stage of organogenesis and is sometimes carried in the fetus for long periods, varying patterns in severity of hearing acuity can occur. The damage due to rubella is mainly sensorineural (Swann, 1944), though there is evidence that the middle ear is also affected in some individuals (Richards, 1964). The fact that the cochlea is impaired makes it difficult to obtain definitive information from audiometric tests. Rubella often causes severe deafness, where the bone conduction loss may be greater than the limits of the audiometer which makes it difficult to diagnose the possible conductive component present (Swann, 1944). The presence of air-bone gaps in rubella children has been reported by Swann (1944) and by Barr and Lundstrom (1961). Richards (1964) reported that a 24 year old female with a severe bilateral mixed hearing loss whose mother had rubella during the third month of pregnancy was found to have a fixed stapes without the accompanying signs of otosclerosis.
After surgery the patient's audiograms showed an improved threshold reading by both air and bone conduction. It is possible that rubella arrests development of the stapes when contracted during the third month of pregnancy (Richards, 1964). Shambaugh (1959) revealed that the stapes in the adult with normal hearing is less bulky than that in the fetus. The stapes found in adults with congenital rubella is bulky and frequently fixed (Richards, 1964).

Recruitment

One anomaly occurring as a result of the disruption of organogenesis in the cochlea is recruitment (Baldursson et al., 1971). Recruitment is defined by Hirsh (1952) as:

"a phenomenon associated with certain types of hearing loss in which the loudness of tones appears to increase more rapidly than normal when the growth of loudness is related to logarithmic increments of the stimulus intensity above the threshold".

The types of hearing impairments that produce recruitment are disorders that affect the hair cells of Corti's organ (Fowler, 1939 and Dix et al., 1948).

Fowler (1939) explained the phenomenon of recruitment based upon principles of neurophysiology. He claimed that when the hair cells in Corti's organ are damaged or missing, stimulus tones will appear weak in intensity when near threshold; but when the stimulus tone is increased the hair cells remaining will be saturated to a degree that the cerebral cortex will perceive the tone as louder than it
would be perceived by a normal, unaffected ear. This phenomena may cause a certain degree of loudness discomfort (Dix, 1967). Recruitment is characteristically absent in deafness due to structural damage of the VIII Cranial Nerve fibers (Dix, 1967).

The presence of recruitment may be a limiting factor in a patient's ability to benefit from amplification (Newby, 1958). The patient who has a greatly compressed range of hearing (dynamic range) may find difficulty in using a hearing aid because when the volume is increased to amplify speech to the point of audibility, the intensity peaks of speech may be uncomfortably loud (Sanders, 1971). Present technology in the hearing aid industry attempts to alleviate this problem through the use of compression circuitry which limits the output of the hearing aid. Thus for the planning of rehabilitative procedures it is important to ascertain whether or not the patient with a sensorineural loss has recruitment.

Tests for Recruitment

The difficulty in demonstrating recruitment of loudness is evident from the many testing methods available (Metz, 1952, Jerger, 1953, Bekesy, 1947).

The alternate binaural loudness-balance test (ABLB) was first described by Fowler (1928). This method requires the listener to match in loudness two tones, both of the same frequency, presented alternately to the two ears. The disadvantage of this test is that it can only be effectively employed in unilateral hearing losses which rarely occur with inner ear disease (Luscher and Zwislocki,
The monaural loudness-balance test (MLB) first suggested by Reger (1936), requires the patient to compare the rate of growth of loudness for two tones of different frequencies measured in the same ear. The main limitation of this test is that the patient must exhibit normal or relatively normal hearing for at least one frequency so that this frequency can serve as the standard to which the sensation of loudness for other frequencies is compared (Luscher and Zwislocki, 1951). The requirement that two tones comparatively close in frequency be used (since frequencies of greatly differing tones are difficult to compare) further limits of the use of this test (Reger, 1936). The MLB test can only be used in cases where there is a sharp drop in audition on the audiogram curve and this pattern is nearly always indicative of recruitment (Luscher and Zwislocki, 1951). Metz (1952) indicated that the diagnostic use of this test is of little significance.

Methods of investigation which are based on the determination of intensity difference limen are of special value (Luscher and Zwislocki, 1951). Hirsh (1952) defines difference limen as:

"the increment in a stimulus which is just noticed in a specified fraction of the trials. The relative difference limen is the ratio of the difference limen to the absolute magnitude of the stimulus to which it is related".

This method of testing is comparatively simple, does not require much time and can be applied irrespective of the type of deafness (Luscher and Zwislocki, 1951 and Hirsh, 1952).
The first test of this type became available following the designing of a new auditory measuring device by Bekesy in 1947. With the device a subject controls the intensity of the test stimulus by manually keying a motor-driven attenuator. The frequencies tested are also changed automatically by this motor-device and allow a mechanically linked ink pen to record the movement of the attenuator on an audiogram form (Bekesy, 1947). These threshold tracings yield a mean intensity variation shown by the length and width of the excursions above and below the average threshold produced in the interval between a just-heard tone and a just-not-heard tone (Hirsh, 1952). The reduction in excursion size was considered to be an indicator of a reduced difference limen for intensity, consequently, an indirect measure of recruitment (Luscher and Zwislocki, 1951). Recent studies by Jerger (1960) and Barr (1971) propose that the Bekesy test may be applicable for diagnosing presbycusis, Meniere's Syndrome, and/or acoustic trauma pathologies, disorders in which recruitment may be a manifestation.

The Luscher and Zwislocki difference limen test (1949) measures the size of the just-heard tone that modulates in amplitude 2 dB at 40 dB above the patient's threshold. The patient hears a pulsating tone or "beats" in intensity. The operator gradually decreases the percentage of intensity change until the patient hears the tone at a steady intensity. Matched against the difference limen scores of normal hearing ears at corresponding sensation levels, the degree of
variation is the point of recruitment. The disadvantage of this test is the added expense of special equipment needed to cause a variation in intensity (Dix, 1967).

Denes and Naunton (1950) suggest another method for the determination of the difference limen. In their method two tone impulses of the same frequency are presented to the ear. The intensity of one impulse is slightly altered from the other and the smallest difference in intensity detected between the two signals is recorded. Again, the added expense of special instrumentation is a disadvantage of this test (Dix, 1967).

The Jerger difference-limen difference test (DLD) (1953) is a modification of the Denes-Naunton technique. The intensity of the tones presented to the ears is presented at different levels above the threshold (sensation level) of the patient at each individual frequency. The differences of these two scores is a measure of difference limen. Special instrumentation which is needed for Jerger's DLD test is expensive which makes this method often impractical.

The measurement of the auditory mechanism employing impedance audiometric techniques was first advanced by Metz (1946). Later studies by Metz (1952) reported that the stapedial reflex can be elicited in normal subjects when a tone stimulus reaches 70 to 90 dB sensation level (SL). Jerger, Jerger, and Mauldin (1972) found that in the normal ear, the threshold of the stapedial reflex to
pure tones is normally distributed around a mean of 85 dB hearing level (HL) with a standard deviation of 8 dB. In the ear with sensorineural hearing loss they found that the SL of the stapedial reflex declines in proportion to increasing hearing to a limiting SL of approximately 25 dB. Keith (1974) proposed that the stapedial reflex be used as an indicator of comfortable listening levels. The only apparent limitations to this method are the presence of a profound sensorineural hearing loss, or middle ear problems that would obscure or abolish the acoustic reflex. In patients showing recruitment the reflex action will occur at less than 60 dB SL (Jerger, 1970). The disadvantage of this test is the need for special instrumentation (Dix, 1967) though perhaps this is somewhat offset by the objectivity of this technique (Metz, 1952) and its capability of being employed in bilateral situations as the reflex occurs in both ears regardless of which ear is stimulated (Metz, 1946).

The loudness-discomfort-level test (LDL) was first proposed by Hood and Poole (1965). This test is of particular relevance since it constitutes a simple method of assessing the presence of loudness recruitment (Dix, 1967). This indirect procedure consists of presenting short bursts of tones at different intensities above the threshold and recording the level at which the patient first experiences a sensation of discomfort (Hood and Poole, 1965). The discomfort level of a normal ear is usually 100 dB as is the
discomfort level of those suffering from end organ lesions. In contrast, the LDL's of subjects with conductive or VIII nerve-fiber deafness exceeded the available maximum audiometer intensity of 110 dB (Hood and Poole, 1965). This test is therefore particularly valuable in establishing the presence or absence of recruitment in bilateral deafness. This test does require a value judgement by the patient and is highly dependent upon instructional phraseology (McCandless and Miller, 1972). It would be assumed therefore that this test also lacks objectivity.
Statement of the Problem

The rehabilitation of individuals who have been auditorily impaired by rubella often involves the wearing of auditory amplification devices. These devices must be fitted and adjusted so as not to cause the wearer any undue discomfort. The hearing aid that amplifies speech sounds to an uncomfortable level will reduce the patient's acceptance of amplification and inhibit the development of his communicative potential. Ideally, the wearing of a hearing aid by those born with such impairments will begin early so that the patient will be able to receive auditory habilitation as language develops (Sanders, 1971). Many methods used in establishing the presence and degree of recruitment have inherent features that make them undesirable when working with rubella children. The subjectivity of most of the methods is an obvious drawback and often the tests are comprised of such complex processes that they are beyond the comprehension of younger or less sophisticated patients. The prohibitive cost of instrumentation designed to aid in the establishing of loudness discomfort levels may also limit its availability. It would seem then, that it would be beneficial to discover a test that could accurately and easily
measure the discomfort level of loudness without expensive instrumentation.

This research will attempt to answer the following questions:

1. Are there significant differences in loudness discomfort levels between normals and post rubella children.

2. Are there significant differences in loudness discomfort levels between continuous and pulsed modes of presentation in normals and rubella children.
Methodology

Test Site

All testing was conducted in the Auditory Research Laboratory at Florida Technological University in Orlando, Florida.

Subjects

Two groups of subjects were required for this study. Group I (experimental) consisted of six children (12 ears) who had been diagnosed as auditorily impaired as a result of maternal rubella. Rubella children were selected from the population of students at a school designed for auditorily-impaired children. Letters to parents (Appendix A) and release forms (Appendix B) were sent to all students that may have been a possible participant. Group II (control) consisted of normal hearing children (12 ears). An attempt was made to match age and sex of the groups. Subjects accepted into either group were tested for stapedial reflex using an impedance audiometer. All impedance testing results were recorded on a standard tympanogram (Appendix C).

Hearing Impaired Group. The children in this group must have a pure-tone air-conduction threshold in either ear of poorer than 25 dB (ANSI, 1969) at 500, 1,000, 2,000 Hz. Audiometric testing
was recorded on a standard audiogram (Appendix D).

**Normal Hearing Group.** The children in this group had pure-tone air-conduction thresholds of 25 dB or better in both ears at 500, 1,000, 2,000 Hz.

**Instrumentation**

**Rooms.** A testing suite (Industrial Acoustics Company Series 1200) was used for all audiometric testing in this study. The noise level of the test room was within the standards set down by the American National Standards Institute for a room used for audiometric testing.

**Impedance Audiometry.** Impedance audiometry used to elicit acoustic reflex measurements was performed using an impedance audiometer (Teledyne Avionics Acoustic Impedance Meter, Model TA-1D). The calibration of the meter was done prior to each session in accordance to guidelines set forth in the instruction book accompanying the impedance meter.

**Pure-Tone Testing.** Pure-tone audiometry was performed using a clinical and research audiometer (Grayson Stadler 1702-A). A matched set of earphones (Telephonics TDH 50) were used for all pure-tone testing. The calibration of the audiometer was checked each day using a Sound Pressure Level Meter (B and K Model 2803). The LDL test was administered with two techniques. The first technique utilized a tone that was automatically pulsed with a duration and interstimulus interval time of 225 msec with a rise time of 20 msec and decay time of 75 msec. The tone was increased
in intensity manually at a controlled rate. After the initial response of the subjects to loudness discomfort the tone was reduced 10 dB then presented in 2 dB increments until a second response was obtained. This procedure was performed ten times at each of the three frequencies and the results of the trials were averaged at each frequency in each ear as suggested by McCandless and Miller (1972). The modified LDL technique was a continuous tone that was also increased at a manually controlled rate. The same procedures used in the pulsed tone technique were utilized in this technique.

**Procedures**

A calibrated check of all equipment was completed prior to each testing session. All individuals were read instructions informing them of the procedures they were to follow (Appendix E). Proper care was taken to insure that the subjects understood the instructions. After each subject was given the instruction and the researcher was confident the individual understood them, he was placed in the testing booth.

The pure-tone hearing test followed the guidelines recommended by Price (1971). The pure-tone air-conduction test was administered with responses recorded on an audiogram. If the subject met the inclusion requirements for one of the groups, he was placed in that group and given a three minute rest period.
The subject was then read the instructions for the LDL test (Appendix E). The LDL was administered according to procedures discussed previously. Results of the LDL test were recorded on the audiogram. The subject was given a 10 minute rest period, then the experimental continuous tone technique of the LDL was administered and results recorded on the audiogram. Impedance audiometric testing for stapedial reflex was conducted according to the guidelines established by Jerger (1970).
Results

Data analysis was performed employing a Chi-square in a 2 x 2 design. Analysis of variance as planned earlier could not be utilized because of the lack of available subjects in the experimental group. It was necessary to combine the scores in the three frequencies in each section of the experiment. Raw scores can be seen in Appendix F. It was also necessary to use descriptive statistics in analyzing the individual frequencies.

Table 1 shows the significance levels between the LDL scores obtained in the comparison of groups within the experimental design.

Differences in loudness discomfort levels between normal and rubella ears were significant at the .01 level. This data lends a positive answer to the first research question. The LDL is in fact significantly different in a comparison between rubella and normal ears.

Results relevant to the second research question are somewhat equivocal. The modes of presentation of the LDL (pulsed and continuous) were significantly different (p = .05) in rubella ears. No significant differences as to modes of presentation were found
# TABLE 1

Significance Levels Between all Pairs of Scores in Normal and Rubella Groups

<table>
<thead>
<tr>
<th>LDL Pairings</th>
<th>$\chi^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal-rubella</td>
<td>6.70</td>
<td>.01</td>
</tr>
<tr>
<td>Pulsed-continuous (rubella)</td>
<td>4.57</td>
<td>.05</td>
</tr>
<tr>
<td>Pulsed-continuous (normal)</td>
<td>.05</td>
<td>NSD</td>
</tr>
<tr>
<td>Rubella-normal (continuous)</td>
<td>7.92</td>
<td>.01</td>
</tr>
<tr>
<td>Rubella-normal (pulsed)</td>
<td>.226</td>
<td>NSD</td>
</tr>
</tbody>
</table>

.05 level of significance = 3.84
.01 level of significance = 6.64
in the normal ears group. The continuous mode of presentation was found to be significantly different in the rubella and normal ear group. The pulsed mode of presentation yielded no significantly different results between the groups.

Table 2 shows the LDL when presented in the continuous.

**TABLE 2**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Normal Ears</th>
<th>Rubella Ears</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>41.6%</td>
<td>16%</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>50%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Loudness discomfort was presented in 41.6% of normal ears at 500 Hz and only in 16% of the rubella ears at the same frequency. Normals had a 50% occurrence rate at 1000 Hz while rubella had 0%. At 2000 Hz the LDL in normal ears was present 50% of the time and 25% of the time in rubella ears.

Table 3 indicates the LDL when the mode of presentation is pulsed.
**TABLE 3**

Percentage of Responses to Loudness Discomfort Levels of Pulsed Pure-Tones for Normal Hearing and Rubella Children

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Normal Ears</th>
<th>Rubella Ears</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>50%</td>
<td>33.3%</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>50%</td>
<td>58.3%</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>41.6%</td>
<td>25%</td>
</tr>
</tbody>
</table>

At 500 Hz the normal ears had a 50% occurrence rate while the rubella ears at the same frequency had a 33.3% occurrence rate. At 1000 Hz the normal ears perceived loudness discomfort 50% of the time while rubella ears perceived it 58.3% of the time. 2000 Hz was perceived as discomforting in 41.6% of the normal ears and in 25% of the rubella ears.

Table 4 illustrates that the stapedial reflex indicating recruitment was found in 80.5% of all the rubella ears though no recruitment was revealed in any of the normal ears at any frequency.
### TABLE 4

Recruitment in Normal and Rubella Children as indicated by Stapedial Reflexes

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Normal %</th>
<th>Rubella %</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>0</td>
<td>75</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>0</td>
<td>66.6</td>
</tr>
<tr>
<td><strong>Average for speech freqs.</strong></td>
<td><strong>0</strong></td>
<td><strong>80.5</strong></td>
</tr>
</tbody>
</table>

Recruitment levels of stapedial reflex = 60 dB (SL)

When the stapedial reflex was compared to the LDL modes of presentation only the rubella ears had the available information necessary for $X^2$ analysis. The difference between the stapedial reflex and both the continuous and pulsed pure-tones was at the .001 level of significance ($X^2 = 11.31$).
Discussion

The results of this research indicate the shortcomings of the modified LDL as a diagnostic tool when dealing with a rubella population. Combined LDL scores (pulsed and continuous) were significantly different between normals and the rubella groups. This finding would indicate that either rubella children do not have recruitment or that the LDL test is inadequate as a measure of recruitment in this population. An analysis of the literature (Baldursson, 1972 and Sheridan, 1964) indicates that recruitment has been well established as accompanying rubella. The difference between LDL modes (pulsed and continuous) was not significant in normals, however this was not the case in the rubella population. Hood and Poole (1966) found that the LDL was elevated above normal by the amount of the conductive loss when the loss was not more than 20 dB.

No previous research has been performed regarding alternative methods of LDL determination. Further evidence of the ineffectiveness of the modified technique (continuous) in this population is the significant difference found between normal and rubella ears when compared with differences when the traditional (pulsed)
technique was employed. There were no differences found when using the traditional method with normal and rubella ears which would seem to indicate that the traditional technique determined the presence of recruitment in this population but to a lesser extent than stapedial reflex.

The stapedial reflex method proved to be an accurate measure of the presence or absence of recruitment in both rubella and normal children. In previous research performed by Baldursson et al. (1972) and Jerger (1970) the ability to elicit a reflex despite significantly raised thresholds indicated some presence of recruitment. The stapedial reflex was present in all rubella children at levels indicative of recruitment at 500 Hz. The recruitment phenomenon was present at three frequencies tested (500, 1000, 2000 Hz) in 80.5% of the total responses. This indication of recruitment in rubella children was significantly different from the combined LDL scores which would imply recruitment in this same population. These findings suggest that the stapedial reflex measurement is a more accurate determinant of recruitment than the LDL.

There may be a number of reasons to explain the inefficiency of the modified technique. Hallpike and Hood (1959) formulated the dual excitation theory that the intensity of specific frequencies evoked the same loudness sensation for all subjects irrespective of the magnitude of the hearing loss. Thus the low intensity
mechanism that subserves the external hair cells is damaged, thus
resulting in a hearing loss, while the internal hair cells, serving
the high intensity mechanism is not damaged and thus is capable of
relaying the sensation of loudness. This built-in mechanism
therefore assigns levels of loudness discomfort at thresholds above
this sensation level. However, Ward et al. (1968) and Beal (1967)
upon surgical investigation of an inner ear damaged by rubella
virus noted a condition similar to the sacculocochlear degeneration
of Scheibe and abnormalities in the cochlear duct. These
abnormalities coincided with endolymphatic fluid depletion which
possibly caused the collapse of Reissner's membrane. Along with
these pathological findings it was noted that there was atrophication
in the Organ of Corti. This pathology may have affected the
capabilities of the hair cells in that the basal turn, the middle
turn and the spiral eminence were all affected (Ward et al., 1968).
With the cells damaged at both the low and high intensity locations
the sensation of loudness in regard to the dual excitation theory
would be altered. Upon this alteration, discomfort to loud sounds
may be absent as the built-in mechanism is no longer intact.

Christie (1969) and Barr and Lundstrom (1961) note that arrested
mental development and retardation are manifested by rubella virus.
These abnormalities are a process of the virus and not a product of
the hearing loss. The medical histories of the rubella children
used in this study did not reveal any such impairments. However,
the hearing loss suffered by these children may have sufficiently hindered their communicative abilities so as to make instructional understanding difficult. To this end, McCandless (1972) found that the instructional phraseology inherent to the LDL is a drawback to the obtaining of consistent responses. Further, McCandless found that a pulsed tone LDL is more easily discernable in children. This may account for the difference between rubella and normal groups when presented with the modified technique and the absence of this difference between the same two groups when subjected to the traditional technique.

This study was confronted with the problem of obtaining suitable subjects for the rubella group. Those children with moderate hearing losses are fitted with hearing aids and subsequently released into the public school system. The locating of these individuals proved to be economically and physically impractical. Consequently, rubella children used in this study were severely to profoundly hearing impaired. Again, this impairment may not have permitted the children to become familiar with the concept of "too loud". It would have been desirable to increase the number of subjects included in the study to yield more definite findings.

Implications for Further Research

An interesting follow-up to this study would be the effects of
how the modified technique of the LDL on subjects whose hearing was moderately affected by congenital rubella. Further investigation is needed in areas concerned with the LDL and conductive and VIII nerve lesions. Further investigation is needed employing the methodology used in this study on known predominantly inner hair cell type pathologies vs known outer hair cell pathologies. This simpler and less expensive technique may someday prove valuable as a measuring technique in the audiologist's diagnostic battery of tests; however, the use of this test on rubella children, profoundly deafened, does not seem practical.
Summary and Conclusions

Congenital rubella is capable of causing hearing losses in children whose mothers contracted the disease as late as the seventh month of pregnancy. This impairment may be compounded by other disorders that occur as a result of congenital rubella. The hearing of these children is effected to the extent that many are fitted with hearing aids and others more severely effected are taught manual communication. Those children fortunate enough to have adequate hearing to be able to wear and benefit from amplification are dependent upon others to correctly make proper adjustments in volume control for them. This adjustment is critical to the rehabilitation of language in the children who may be hearing speech for the first time. Upon raising the volume of these aids a phenomenon referred to as recruitment may occur. Recruitment may be briefly defined as an abnormal sensitivity to loud sounds. Investigation of the literature shows this to be true in rubella children. The detection of recruitment is primarily used for diagnosing types of hearing disorders (conductive vs sensorineural vs central). The literature also reveals that current techniques of detecting recruitment are either costly or restrictive to unilateral losses. Typically, the rubella child is bilaterally effected.
The LDL has been proposed as a solution of recruitment testing. It was therefore decided to investigate the effectiveness of the LDL on rubella children and to test a simplification of the traditional mode of LDL presentation.

A group of rubella children and a group of normal children were initially tested for the presence of recruitment using an impedance meter to elicit a stapedial reflex. The children were then exposed to two modes of LDL presentation. Subsequent (aP) analysis was performed on the groups and different modes of presentation. The results indicated that there were differences between rubella and normal ears in relation to LDL levels and that the continuous tone technique was not as effective as the traditional pulsed tone technique. It was found that the stapedial reflex was the most efficient method of finding recruitment, even though this method employs expensive equipment that was prohibitive to some on a restricted budget. The rubella children used in this study were severe to profoundly deafened resulting in possible language barriers and certain physiological dysfunctions not suitable for the LDL. The LDL may be of some diagnostic use to the audiologist but was shown impractical with this population of rubella children.
Dear Parent (s):

We are presently engaged in research which will hopefully result in gaining more information about the hearing abilities of children suffering from sensorineural impairments. If your child qualifies for inclusion as a subject in this study I will again be in contact with you to discuss the particulars of our study and try to arrange a mutually convenient time for your child to be tested at the Communicative Disorders Clinic at Florida Technological University here in Orlando. Attached you will find a form which requires your signature before we are allowed to examine the school's records related to your child's hearing impairment. Also, it is necessary for us to have the second attached release form signed by the parent in order for us to use the data found in the research. Naturally, no names, addresses or identifying information will be made available to anyone. Should you have any additional questions about our research, feel free to telephone either Dr. Thomas Mullin or myself at 275-2681.

Again, please accept our thanks for your cooperation in this research endeavor.

Cordially,

Mark A. Kenzik
Graduate Research Assistant

Thomas A. Mullin, Ph.D.
Associate Professor
APPENDIX B

Record and Press Release Forms

SCHOOL RECORDS

I hereby grant permission to Rock Lake Elementary to release to Mark Kenzik information pertaining to my child [_______________________]

Date: [_______________________] Signature: [_______________________]

PRESS RELEASE

I hereby grant [____] deny [____] permission for the use of any data collected on my child [_______________________] while a student under Mark Kenzik from Florida Technological University. I understand this data will be used for educational purposes and/or connected with the university and at no time will they be used for commercial purposes.

Date: [_______________________] Signature: [_______________________]
APPENDIX C

Standard Tympanogram
LEFT EAR TYMPANOGRAM

RIGHT EAR TYMPANOGRAM

ACOUSTIC REFLEX STIMULUS IN 40 HL

ACOUSTIC REFLEX STIMULUS IN 40 HL
APPENDIX D

Audiogram Form

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HEARING THRESHOLD LEVEL IN DECIBELS RE ANSI 1969 STANDARDS

-10 0 10 20 30 40 50 60 70 80 90 100 110
Hello,

My name is Mr. Kenzik and I am a graduate student at F.T.U. I'm going to give you a brief series of hearing tests. First, I want you to give me the following on this piece of paper:

1) Name
2) Age
3) School

Pure-Tone Audiometrics

In the first part of this test you are going to hear some tones like little whistles. Every time you hear the tones, press the button. When you no longer hear the tones release the button. Remember, only press the button when you are very sure you hear the tones. The tones will get very faint at times, so be sure to listen closely.

Do you understand?

LDL

In this part of the test I want you to press the button when the tones get too loud. Remember, don't press the button when it begins to get loud but press the button when it gets too loud or
uncomfortably loud. After pressing the button, keep it depressed till I say to let it go.

Do you understand?

**Impedance Audiometry**

The last part of the test is easy. All you have to do is remain quiet and still for a few minutes.

Thank you for your cooperation.
APPENDIX F

Raw Data
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<th>LDL Continuous</th>
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