ADMINISTERING THE AUDITORY COMPREHENSION TEST TO A GROUP OF LEARNING DISABLED SUBJECTS

DAVID A. MACLEAN ©

A THESIS SUBMITTED TO THE FACULTY OF ARTS

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF ARTS

DEPARTMENT OF PSYCHOLOGY

LAKEHEAD UNIVERSITY

THUNDER BAY, ONTARIO

JULY, 1990

ISBN 0-315-63194-5

I would like to dedicate this thesis to my father, who taught me the value of hard work, dedication, and honour. To my mother, who taught me to love, to be compassionate, and to care for others. Finally, to those friends who stuck beside me in my times of need. To Shannon, to Shelley and to Victoria.

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. Margaret Sellick, and to Dr. Scott Sellick for their guidance, advice, and support throughout the whole of this study. Their dedication to excellence has helped make the experience challenging, exciting, and rewarding. Thanks also to the teachers, principals, and support staff of the Lakehead Board of Education for their considerable help in securing a strong sample of subjects for this study.

Table of Contents

List of Tables

Abstract

This study attempted to replicate the finding by Green and Josey (1988) in some groups of learning disabled children of better comprehension of spoken language in one single ear (monaural condition) than in both ears together (binaural condition). The Auditory Comprehension Test (ACT) which is designed specifically to measure this "binaural deficit" was administered to 36 learning disabled children, from which a subgroup of learning disabled subjects judged by teachers to have prominent difficulty comprehending everyday speech was later selected, and a control group of 36 non-learning disabled children individually matched for age, sex, and IQ with the learning disabled children. The ACT involves presenting short news item-style stories via headphones to either ear alone, or both ears simultaneously. After each story the subject repeats as much of the story as s/he can remember. The resulting three scores (left ear, right ear, and both ears simultaneously) are compared to determine if listening with either single ear produces better comprehension than listening with both ears together

(i.e. to see if a binaural deficit exists). Comparisons between the control and learning disabled groups revealed significant differences in the direction of (1) higher average test scores for the control group, and (2) higher overall binaural deficits for the learning disabled group, as well as a larger number of subjects in the learning disabled group having a binaural deficit. The control group also performed significantly poorer in the binaural condition than in either single ear alone, indicating a possible bias in the ACT itself, and/or a possible selection bias. The test bias points to the need for revisions to the ACT in its application to children.

Introduction

According to the definition devised by the National Advisory Committee on Handicapped children in 1968, "disorders of listening, thinking, talking, reading, writing, spelling, or arithmetic" may be considered under the general heading of learning disabilities. (in Reid and Hresko, 1981). Of the functions listed, perhaps the most debilitating is not being able to comprehend or remember the spoken word. A problem in understanding spoken language both contributes to many potential problems in reading, writing, and arithmetic, and confounds every attempt to remediate the varied problems. This is because all remediation itself must rely to a significant degree on the very skill which is deficient: the ability to comprehend, and hence respond appropriately to, verbal instruction.

If many of the everyday problems faced by learning disabled children may be exacerbated by a comprehension problem, their classroom performance may be expected to show its greatest effects. Since classroom instruction relies so heavily on verbal direction, the child who fails to comprehend or retain a few crucial points in a math lesson will lose the whole lesson. And if the problem is not caught immediately it will also affect all subsequent lessons which are based upon this original one. Thus an auditory comprehension problem compounds itself over time, and also has the potential to affect many diverse areas of the learning disabled child's academic life.

Unfortunately such a problem also affects the child's social and home life. Peers as well as family may become increasingly frustrated with the child, giving more negative responses and thereby reducing the child's self-esteem. The child may also become frustrated from repeated failures in social situations and subsequently withdraw.

Since verbal comprehension and retention is of such importance in learning, a method of detecting and remediating problems in these areas could be of potential value to many learning disabled children. While there are tests which measure auditory comprehension, a recently developed test called the Auditory Comprehension Test (ACT) seems, at least from preliminary studies, to be a promising new candidate in the area. This test is unique among tests measuring auditory comprehension in that its goal is the detection of a very specific, and until recently, unrecognized deficit: the ability in certain individuals to comprehend complex speech better when it is presented to one ear than when it is presented to both ears. To understand how this could occur, it may be helpful to trace the development of the ACT from its origin in theory to its present form.

Development of the ACT

The initial observations which eventually led to the development of the ACT started with the finding that schizophrenics, in comparison to normal controls, had difficulty in the transfer of information about a manual task from one hemisphere to the other (Green, 1978; Hatta, Yamamoto and Kawabata, 1984). Green then postulated that if information about a manual task was improperly transferred between the hemispheres, then processing of other sensory information might similarly be impaired. To test this hypothesis, Green and Kotenko (1980) presented tape recorded stories taken from Neale's Analysis of Reading Ability (1966) to schizophrenic patients. Some stories were presented to the left ear only, some were presented to the right ear only, and some were presented to both ears simultaneously. The patient was required to answer questions following each story. Based on the results of the studies involving the manual task, it was hypothesized that, while normals would perform equivalently in all three conditions, the schizophrenic subjects would show deficient comprehension on stories presented to the left ear. The results showed not only this predicted left ear (right hemisphere) deficit in comprehension of auditory information among schizophrenics but, surprisingly, a "binaural deficit" as well. That is, their comprehension with both ears was not as good as their comprehension with the right ("superior") ear alone, while the normals showed no such comprehension deficit. It has been theorized that when speech is received in both ears for these individuals the inferior ear interferes with the otherwise normal comprehension of the superior ear, thus decreasing comprehension. When an absolute binaural deficit was calculated for both a control group and the schizophrenic group (see Appendix A) the difference between the groups was significant. These results were later replicated in a group of acute schizophrenics in comparison to a control group (Hunter and Green, 1985; Green, 1985).

Although the comprehension test as it existed at this point was effective in illustrating the ear differences in certain groups, it was felt that certain improvements were necessary. The test was subsequently shortened and a new scoring format was devised. Also, at this point, a second test situation was developed to test the hypothesis of a binaural deficit in those subjects found to possess it at the time of the initial testing. It essentially involved re-presenting the stories in an open field (no headphones) with the subject alternating between listening while wearing a wax earplug in the inferior ear and listening with both ears unplugged. The resulting test was named the Auditory Comprehension Test (for a detailed description of the ACT, see the Method section).

Theory Concerning the Binaural Deficit

Although auditory signals received at each ear result in neural stimulation of both hemispheres of the brain, the primary neural pathways from each ear, making their way to the cerebral cortex, are contralateral. Thus, the stimulus received at the right ear proceeds primarily to the left temporal lobe. The stimulus received at the left ear, however, proceeds first to the right hemisphere and must then cross the corpus callosum and proceed to the left temporal lobe where language is processed (in people who are left hemisphere dominant for language). Under normal circumstances this process occurs without mishap and the auditory information can be processed in the dominant hemisphere, after which the appropriate response can be made. However, Green theorized that under some circumstances (for example in schizophrenics and some other clinical groups) a problem arises in the intercommunication between the hemispheres such that the normally complementary nature of the information from the two ears is lost. As Katz and Wilde (1985) state: "the 'poorer ear' ... may in fact disrupt the performance of the 'good ear'." (p. 285). Green proposes that where an abnormal binaural deficit occurs, an earplug be worn in the inferior ear, to reduce the "noise" created by its stimulation. When this is done, an increase in the individual's comprehension is the result.

We would expect that a deficit could occur in either ear because proper comprehension of complex speech theoretically involves the participation and cooperation of many different brain areas in both hemispheres (Green, 1983, p. 294). We would, however, expect the left ear to be the inferior ear more often than the right ear because the longer left ear pathway increases the chance of damage occurring. In fact, Green finds a ratio of approximately 2:1 "left ear" to "right ear" damage.

Now that some of the rationale and the theory behind the ACT has been explained, it remains to be shown how the ACT may justifiably be applied to learning disabled populations.

ACT Results with Children

The finding of a binaural deficit in adult schizophrenics, along with its hypothesized neurological, and possibly genetic, basis led Green and other researchers to wonder if such problems existed in children at "high risk" for developing schizophrenia in later life. Since on average only one out of every ten children of schizophrenics later develops the condition, one might expect that the adult findings would not be so clearly evident among children. One study undertaken to investigate this hypothesis (Hallett and Green, 1982) did, in fact, find a significant binaural deficit in the high risk group ($p < .025$) but not in a matched control group of children who did not have a schizophrenic parent.

The finding of a binaural deficit in this group of at-risk children acted as a catalyst for more research with special groups of children much as the findings with adult schizophrenics had done. Of the groups subsequently tested, the most important for our purposes were the learning disabled children. Although no formal papers on the use of the ACT with learning disabled children were published until quite recently, Green tested a number of children in the process of standardizing the ACT. Some of these were children of psychiatric patients. Green (personal communication, 1988) also tested 36 learning disabled children whose teachers or parents believed them to have prominent auditory discrimination or memory problems, but who had been found to have no hearing impairment. T-tests showed that on the average, as a group, the highest single ear score for these specially referred children (in some cases the left ear and in some the right ear) was significantly greater than the binaural score, indicating that for some of these children listening with both ears resulted in much poorer comprehension than listening with the one good ear alone. Furthermore, when tested on a second occasion some time later with the poorer ear plugged, there was a strong positive correlation (r= .66) between the plug condition score and their highest monaural score from first testing. That is, when the poor ear was plugged, the child's comprehension was improved almost up to the level of the single "good" ear score from their first testing. These results both confirm the initial hypothesis - that of a binaural comprehension problem in some children - and provide preliminary support for the potential effectiveness of wearing an earplug in increasing speech comprehension in this group. The present study, since it is preliminary in nature, will not involve any earplug testing.

The Green and Josey Study

More recently, Green and Josey (1988) investigated the above finding in a much larger sample of learning disabled children. The study involved three groups of children: A normal control group (group 1), a group of heterogeneous learning disabled children (group 2), and a group of learning disabled children in which the primary problem was thought to be in the area of auditory processing (they were reported by the teacher as primarily having difficulty paying attention to, understanding or remembering speech). Due to the importance of this study to the present investigation, the patterns of results of ACT testing will be presented in detail.

Normal sample. The control group consisted of 132 subjects. This large sample size led to some new findings. The first was that of a significant difference between the mean binaural score and the mean monaural score (of whichever single ear was the greater) ($p < .004$). The normal subjects were better at comprehension and recall of binaurally presented speech. Another surprising result was that males (although matched for age and IQ) performed significantly better than females on mean ACT recall ($p < .002$). As would be expected from results with other normal populations, mean ACT score was positively correlated with verbal IQ ($r = .57$ for males and $r =$

.42 for females) as well as with the age of the subject (r = .42 for males and r = .65 for females).

Heterogeneous learning disabled sample. This sample consisted of 88 subjects. Their mean recall score (the total of their left ear score, their right ear score and their binaural score divided by three) was significantly lower than the control group (p < .001). Also, in contrast to the control group, the mean binaural recall score was significantly lower than the mean of the two monaural scores (p < .0001). The percentage of children in this group showing a binaural deficit was 45%. The same sex difference found in the control group emerged again in this group (p < .001).

Whereas we would expect a high positive correlation between verbal IQ and ACT scores in a normal sample, we would not expect one in a learning disabled sample since these children are of normal intelligence but are more likely to possess a comprehension problem. Accordingly, no correlation was found between the mean ACT score and verbal IQ, but a positive correlation between age and ACT was found (r = .74 for males and r = .65 for females).

Selected learning disabled sample. This group consisted of 18 specifically selected subjects with identified auditory comprehension problems (as identified by the child's teacher). As expected, a significant difference was found between this group and the control group in terms of the relative advantage of the monaural over the binaural scores ($p < .0001$). That is, as in the heterogeneous learning disabled group, these children were impaired in comprehension using both ears relative to their comprehension using the superior single ear. Further, whereas only 45% of the heterogeneous learning disabled group had impaired binaural scores, 72% of this specifically selected learning disabled sample were found to be impaired binaurally. Also, as in the other learning disabled group, no correlation existed between the mean ACT score and verbal IQ.

Summary. The results of the study by Green and Josey (1988) revealed that in the normal population the binaural listening condition (i.e. listening with both ears) usually or normally leads to the best comprehension. However, for approximately 45% of the heterogeneous learning disabled children and 72% of the selected learning disabled sample the reverse is the case. A monaural condition (that is, listening with a single ear) is, on average, superior to the binaural condition. Also in normal subjects, the mean ACT score is positively correlated with verbal IQ. With learning disabled subjects, their verbal comprehension seems to be independent of their verbal IQ. It is possible, for example, for a bright person to have a low ACT score and for one with a lower IQ to have a higher ACT score. The ACT derives much of its value from bringing some of these children up to their potential, at least in comprehending and recalling verbal information. The potential benefits of this, as previously alluded to, could be far-reaching.

Earplug treatment results. When initial results of the Green and Josey (1988) study indicated a binaural deficit (see Appendix A), an earplug was fitted for a second testing (see Method section for a discussion of this procedure). This resulted in the identification and re-testing (with and without earplugs) of 40 of the 88 children from group 2. As predicted, the earplug condition gave significantly better recall scores than the non-earplug condition

(p < .0003). In group 3, 13 of the 18 children were identified and re-tested, with similar results (p < .0005).

The results of these studies of groups of learning disabled children seem to indicate that the ACT not only detects auditory processing problems but also points to a means of remediating these problems. Appendix B provides the results of an evaluation of earplug effects based on parent's reports. It gives us some idea of the possible benefits of the treatment procedure outside the artificial test setting.

The Present Study

With the preceding results in mind, the present study will attempt to replicate some of the findings in a group of learning disabled children. If findings are similar to those reported by Green, some of the children tested in the Lakehead Board of Education schools might ultimately benefit from wearing an earplug in daily life. The following hypotheses are proposed: (1) That the group of learning disabled children will score significantly lower on mean ACT score than will the normal controls; (2) that the group of learning disabled children will show a binaural deficit but the control group will not; (3) that a larger number of learning disabled subjects than control subjects will possess a clinically significant binaural deficit (see Appendix A for what constitutes an abnormal binaural deficit).

Method

Subjects

Written consent was obtained from parents before any assessment procedures were undertaken (see Appendix C for the consent letters). Two groups of subjects were selected: one group of heterogeneous learning disabled subjects, and one group of control subjects. A subgroup of learning disabled subjects was also isolated from among the learning disabled group on the basis of the criteria listed below.

Learning disabled group. A group of 36 children between the ages of 7 and 14 years who have been identified by the school board as being learning disabled were selected based on the following criteria:

1. Possess a full scale IQ no lower than the low average range.
2. Have normal hearing
3. Auditory processing problem is the most

prominent problem (i.e. no other explanation such as hyperactivity or attention deficit can be applied to account for this problem).

Consent letters were sent out to parents describing the ACT, its purpose, and some previous findings, and almost all the parents returned their forms granting consent to test. There were on average no more than two students in any one class who did not take part in the study, either because they failed to return the form or because parents felt they had been "tested enough already this year".

In addition, a subgroup of learning disabled subjects was identified from among these 36 subjects based on the following criteria: Teacher reports that the child possesses one or more of the following:

a. Has problems paying attention when spoken to.
b. Seems to "tune out" at times.
c. Has problems following two or three simple instructions.
d. Forgets what is said.

Control group. Thirty-six control subjects were selected to match the learning disabled subjects for age, IQ, and sex. The age of each control subject was matched to that of his or her learning disabled partner within six months. The IQ of each control subject matched the IQ of his or her paired learning disabled subject within one standard error of measure of the best estimate of intelligence. With some learning disabled students it was decided that, since some subjects would be impaired on verbal portions of the WISC-R, the performance IQ would be a better estimate of the intellectual capacity of the child. Therefore, the best estimate of overall intellectual capacity was deemed to be whichever of the two scales was higher, and the control subjects were matched to this IQ score. The control subjects also had to have normal hearing and have no known learning problems.

These subjects were recruited in a manner similar to the learning disabled subjects, in that consent forms were sent out to parents describing the ACT and asking for volunteers to act as normal matches for the learning disabled subjects already tested. A list of potential normal matches based on age of the student was compiled from class lists and, in most schools, the principal would distribute the consent forms, and keep track of their return. In the case of the control subjects it was frequently necessary to send out a second round of consent letters since the refusal rate was much higher among the control subjects than among the learning disabled subjects. Substantial cooperation from the principals and teachers was obtained throughout the whole time of the data collection. Since no full scale IQ scores were available for the control subjects, all were given the vocabulary subtest of the Wechsler Intelligence Scale for Children - Revised (Wechsler, 1974) and a full-scale IQ score was estimated from this.

Procedure

Both groups were tested using the ACT in the standard form described below. This testing took place within the school during normal school hours. Each subject for whom consent was obtained was removed from the classroom and brought to a private room where undisturbed quiet could be insured. The subject sat across a table from the experimenter and was delivered the standard instructions described below.

Apparatus

(1) The Auditory Comprehension Test kit (described

in detail below), includes: A pre-recorded audio cassette tape of the ACT stories, a cassette player, two sets of headphones and a switching box to allow routing of the stories to each ear individually or to both ears simultaneously, and a test answer sheet (see Appendix D) to be used by the test administrator to record the student's responses following each story. (2) The WISC-R was also used with all control subjects.

The Auditory Comprehension Test

Test form. The ACT was developed by Paul Green (Ph.D.) and Elaine Kramer (Hearing Aid Audiologist). It consists of 30 stories divided into 5 subtests (Tests A, B, C, D, and E). Each of the six stories within each subtest are of equivalent length in words and contain equal numbers of items to be recalled. The items are "arbitrarily defined units of meaningful information, mainly nouns such as 'kitten', verbs such as 'arrived' and adjectives or adverbs." (Green, 1983, p. 286). The subtests increase in difficulty from Test A through Test E (see Appendix D).

Administration. The stories contained in each subtest have been recorded on a standard audio cassette. They are presented via earphones to the subject in the following order: the first story (e.g.in Test A, story 10.1) is presented to the left ear, the second story (10.2) to the right ear, and the third story (10.3) to both ears simultaneously. This order is repeated for stories 10.4, 10.5, and 10.6 and similarly for the remaining subtests (see Appendix D). Each child will thus hear 30 stories, 10 having been heard in the left ear, 10 in the right ear and 10 in both ears simultaneously.

After the appropriate rapport has been established, the subject is told that s/he will be given a test to measure how well s/he can listen to and remember what people say. The standard instructions are as follows:

"On this tape there is a woman reading some short stories. I want you to listen to each story and as soon as it is finished, I want you to tell me as much as you can remember about the story, in your own words. Sometimes the story will be in this ear (pointing to the headphones), sometimes in the other ear and sometimes in both ears. Don't worry if you can't remember it all. Nobody can remember all of a story. Just listen carefully and try your best. Is that clear? "(Explain further if not) (Green and Kramer, 1984).

Once the subject understands the instructions, the tape is started; with the first story routed to the left ear of the subject. The tester will hear the stories through a separate pair of headphones. Once the first story ends, the tester pauses the tape and states: "tell me as much as you can remember". As the subject recalls the story the tester checks the appropriate boxes on the test form (Appendix D) until all are checked or the subject indicates that s/he cannot recall anything more. The tester then switches the signal to the right ear and allows the next story to be presented. The stories are administered in the order indicated above until all thirty stories have been administered.

Scoring. Summing the number of check marks yields a score out of a maximum of 160 for each condition (left, right, both). A score for the number of misinterpretations in each condition is also calculated. A misinterpretation, or "intrusion" can occur if the order of the events in the story is rearranged (for example, in Test B, 10.6: "They saw a dog on a trapeze/ and a monkey/ riding/ a donkey"). The story is scored for all the correct items but a note is made of the intrusion of new meaning into the story by placing a star to the left of the story. A second type of intrusion may involve the addition of items or replacing of one name with another.

The totals for each subtest, along with the number of intrusions are entered on the appropriate line at the top of the record form and totals are then calculated. Comparisons can then be made to determine if a "binaural deficit" (see Appendix A) exists and hence if an earplug treatment may be of potential benefit.

Reliability

Parallel form. Since the range of difficulty within each of the five subtests of the ACT is so small, the three different test conditions (left, right, and binaural) may be considered to be three parallel forms of the test. Pearson product-moment correlations between the scores in each condition with scores in every other condition for the 52 subjects in the initial adult standardization sample resulted in:

r(Left Right) = .82 (p < .01)
r(Right Both) = .66 (p < .01)
r(Left Both) = .82 (p < .01)

A standard error of measure (based on r = .82) was calculated to be 9.25 (Green, 1983).

Test-retest. Twenty subjects were tested twice on the ACT after an interval of approximately three weeks by Green (1983). The mean scores for these 20 subjects were as follows:

First test: 98.79 (s.d.= 10.19)
Second test: 109.26 (s.d.= 12.24).

Correlating the scores for the 20 subjects between test and retest yields a coefficient of $r = .86$ ($p < .01$) which by way of comparison is greater than that of 9 of 11 WAIS-R subtests (Wechsler, 1981). The standard error of measure computed for this correlation was 5.19. While it is true that re-testing results in improved performance on the ACT, it should be remembered that it is the pattern of clear superiority of one ear listening over binaural listening which is diagnostically important, not the absolute scores.

Inter-rater reliability. Because the scoring of the ACT is relatively objective, inter-rater reliability of trained testers has been high, at .90 - .94 (Green, 1988, personal communication). From these formal measures it appears that the ACT has a high degree of reliability.

Validity

It should be noted that because the ACT is based on very recent findings, no similar test exists against which to compare the ACT. Therefore most of its validity comes from its practical uses in schools and hospital settings where it appears to be effective in identifying auditory processing problems. As Appendix B demonstrates, the remediation that follows from the results of ACT testing can have beneficial effects and this adds to the test's validity.

As a measure of realistic speech comprehension and recall, the ACT appears to possess strong content validity. The skills required to respond to the test items are the same ones required in everyday speech comprehension. Although rote memory may be used to give word-for-word accounts of the easier stories, the later, more difficult stories require comprehension and retention of their content in order to score well.
The high positive correlation among normal subjects between the mean ACT scores and verbal IQ (r= .479) is indicative of construct validity. We would expect a subject with an IQ of 120 to have better verbal comprehension and recall scores than a subject with an IQ of 100. A further indication of validity comes in the form of the efficacy of the ACT earplug treatment in improving everyday speech processing (see

Appendix B).

<u>The Earplug Treatment</u>

Although beyond the scope of the proposed study, this section is presented for the sake of completeness. Those subjects identified as having an abnormal binaural deficit (see Appendix A) on first testing are re-tested under different conditions to confirm the "hypothesis" of the binaural deficit Instead of headphones, the subject is given a wax earplug to gently fit in the ear indicated to be inferior based on initial testing. The tape recorded stories are played in an open field at a comfortable volume. Three stories are presented with the plug inserted in the ear followed by three stories presented with the plug out (the normal listening condition), with this procedure being alternated throughout the test. The results are tabulated in the same way as in first testing except that with only two conditions the totals for each condition are out of 240 (480/2) instead of 160 (480/3). Those subjects who continue to show significantly better performance in the monaural condition may then wish to attempt wearing an earplug in daily life. The usual procedure in such instances is to refer the child to a physician and to an audiologist for earplug fitting.

Results

Demographic Data

The average age of the control sample, which was matched for age to within 6 months, for IQ, and for sex, was 11 years - 11 months, with ages ranging from 8 years - 1 month to 14 years - 2 months. The average age of the learning disabled sample was 12 years - 2 months, with a range from 8 years - 5 months to 14 years - 6 months. The sample included 62 males (86.1%) and 10 females (13.9%), selected from five schools in the Lakehead Board of Education. The disproportionate number of males to females results from the fact that the Special Education classes in the Lakehead Public School System contain comparatively few females in relation to the number of males.

The results were analyzed in three different ways: overall scores were analyzed, then scores for subjects below twelve years of age were compared to those subjects 12 years of age or older, and finally a shorter form of the ACT was examined. The results for the selected learning disabled group (N=19) are presented in a separate section.

Overall Score Analysis

An ANOVA comparing the overall mean scores for the two groups ((L + R + B) / 3) was significant (F = 25.96, $p < .0001$), indicating that the learning disabled subjects performed poorer overall than did the control subjects (see Appendix E, Table E-1). Further, a significantly larger number of subjects in the learning disabled group possessed a clinically significant binaural deficit (defined by Green (1983) to be a deficit of -20% or more) than did the matched control subjects (X (1, N=72) = 4.19, $p < .05$). In the learning disabled group, 15 of the 36 subjects (41%) were found to have a significant binaural deficit, whereas 7 of the 36 matched control subjects (19%) displayed a significant deficit. It should be noted, however, that while the number of learning disabled students found to have a binaural deficit closely approximated the number reported by Green and Josey (1988) on an Alberta learning disabled sample (45%), the latter finding that 19% of the control sample also possessed a binaural deficit is unexpected.

The binaural deficit was calculated according to the following formula:

$$\frac{B - HS}{B} \times 100$$

where B = the both ear score,
and HS = the higher single ear score,

and the group means are presented in Table 1 below.

Table 1

Binaural Deficits and Standard Deviations for the Two Groups

	Binaural Deficit	Std. dev.
Control Group	-11.49	10.43
Learning Disabled Group	-19.72	17.49

The difference between the mean scores for these two groups was significant, F (1,71) = 5.87, $p < .02$, indicating that the learning disabled group possessed a larger mean deficit than did the control group (see Appendix E, Table E-2). However, the interpretation of this result is complicated by the fact that the control subjects, among whom, theoretically, there should be at least equivalent performance across the three conditions (left, right, and both ears), showed significant differences between the left ear and both ear conditions (t (35) = 3.00, p = .005), with the both ear score being lower, and between the right ear and both ear condition (t (35) = 4.36, p < .001), again with the both ear score being lower (see Table 2 for the means and standard deviations in the left, right, and both ear conditions). Since we would expect the control subjects to perform equivalently on all three possible conditions (left ear alone, right ear alone, and both ears together), or even to be superior in the binaural condition (as found by Green & Josey, 1988), this finding of lower both ear scores presents a potentially serious problem in interpreting our data.

This discrepancy between the present findings and Green and Josey's (1988) previously reported findings could be due to three possible explanations:
(1) A story effect such that the stories presented to the two ears together are more difficult for the children to comprehend, resulting in lower scores for the both ear condition, and/or (2) A selection bias

Table 2

Group Means and Standard Deviations for the Three Listening Conditions for the Three Different Analyses Performed

		LEFT	RIGHT	BOTH
OVERALL SCORES	CONTROL (N=36)	95.83 (22.19)	96.47 (18.27)	90.53 (17.95)
	L.D. (N=36)	70.56 (21.08)	76.89 (18.63)	67.17 (19.79)
< 12 YEARS	CONTROL (N=16)	85.25 (23.17)	86.81 (20.03)	81.75 (19.87)
	L.D. (N=15)	60.47 (18.77)	68.07 (14.98)	55.33 (15.82)
≥ 12 YEARS	CONTROL (N=20)	104.30 (17.71)	104.20 (20.03)	97.55 (12.86)
	L.D. (N=21)	77.76 (20.01)	83.19 (18.72)	75.62 (18.16)
SHORT FORM	CONTROL (N=36)	49.25 (7.52)	49.67 (7.31)	46.58 (7.48)
	L.D. (N=36)	37.81 (9.40)	40.86 (9.00)	36.75 (9.16)

such that the control group in the present study contained a larger number of children with binaural deficits, and/or (3) Tester error.

This third possibility can be effectively ruled out since the tester in the present study was trained by a colleague who worked with Dr. Green at Alberta Hospital Edmonton from 1982 to 1986. Supervised training continued until no more than two points separated their scores in any particular condition (left, right, or both ears).

A selection bias is a more likely possibility, and may have resulted from the method used to recruit subjects for the control group. Since the consent form sent to parents contained a letter of introduction describing the comprehension problem that the ACT is designed to measure, it is possible that those parents who believed their child to be performing below potential, would have been more likely to consent to testing.

A story effect can also be hypothesized to have caused the observed discrepancy, especially in light of the fact that the stories are not of equivalent difficulty for children, as Table 3 below shows.

Table 3

Means and Standard Deviations Obtained by the Control Subjects on each Individual Story on the ACT.

	Mean recall scores (Standard deviations)					
	Story 1 Left	Story 2 Right	Story 3 Both	Story 4 Left	Story 5 Right	Story 6 Both
Subtest A	7.00 (1.66)	6.85 (1.89)	8.15 (1.69)	8.46 (1.56)	7.28 (1.77)	6.04 (1.52)
Subtest B	5.85 (2.02)	7.24 (1.82)	9.04 (1.46)	8.78 (1.32)	7.70 (1.33)	5.65 (1.77)
Subtest C	8.24 (2.73)	10.85 (2.03)	10.85 (2.46)	10.57 (2.43)	9.26 (2.07)	6.56 (2.49)
Subtest D	11.89 (4.06)	10.91 (2.97)	9.41 (3.76)	10.83 (3.90)	11.15 (3.16)	7.72 (3.94)
Subtest E	11.35 (4.99)	13.35 (4.60)	13.63 (3.66)	12.59 (5.64)	12.11 (4.37)	12.46 (3.74)

Note. Left, right, and both refer to the ear to which the column of stories was presented.

Thus, there may be a systematic discrepancy in the difficulty levels of the stories such that the stories presented to both ears are more difficult for children to comprehend, resulting in lower overall scores in the both ear condition. According to the formula for the binaural deficit (((B - HS)/B) X 100), we would expect inflated numbers of significant binaural deficits under such circumstances. That is, if as is suggested by the data, the "both ear stories" are as a group more difficult than either the left or right ear stories (see Table 3 and, for comparison, Appendix A, Table A-1), then even the normal subjects will perform more poorly on them, will receive deflated "both ear" scores, and will be more likely to display significant binaural deficits on the test (when in reality they do not possess a deficit).

In order to test these hypotheses, the total scores obtained by each individual control subject in the three conditions were plotted on a graph. If it is true that the control sample really contained more subjects with genuine binaural deficits rather than just "apparent" binaural deficits created as an artifact of a story effect, then we would expect a number of subjects in this sample to have total scores for one ear substantially higher than both the other single ear total and the both ear total (i.e. L=95, R=87, B=88). If there are not many subjects displaying this pattern, then we would expect a large number of subjects to have patterns similar to the overall mean score patterns obtained on the ACT (i.e. L=95, R=96, B=90), and it could be concluded that the test itself contains the bias. When the plot is examined, 15 of the 36 subjects show a pattern following that which would be expected for a story effect, and 6 of the 36 show a clear pattern expected for a binaural deficit. Of note, only one of the 36 subjects showed a trend favouring the binaural condition over either single ear, which is the trend we would expect the majority of subjects to follow.

In addition to the above, a t-test was done on the total scores for the control group after those subjects who showed a deficit greater than -20 percent, and who also showed the pattern of scores that would be expected for a subject with a binaural deficit had been removed. If only the selection bias is operating, then removing those subjects with binaural deficits should eliminate the discrepancy in the scores obtained by the group as a whole. Both the left ear and right ear scores, however, remained significantly higher than the both ear scores, with $t(31) = 2.29$, $p < .03$, and $t(31) = 3.51$, $p < .001$, respectively.

Analysis of Younger and Older Subjects

Since the stories on the ACT were designed and pretested on an adult population, it was thought that perhaps the extent of the problem with the lower binaural scores might be limited only to the younger children, whose comprehension of the more difficult stories would be impaired relative to that of older children and adults. Consequently, an analysis of the results for those control subjects under 12 years of age ($N = 16$), and those 12 years old and older ($N = 20$) was undertaken (see Table 2 for the means and standard deviations for this analysis). The lower binaural scores persisted in this younger group, with the right ear mean score being significantly higher than the both ear mean score ($t\ (15) = 2.26$, $p < .05$). Interestingly, a lower binaural score was not found when the left ear score was compared to the both ear score, $t\ (15) = 1.45$, $p = .17$, although the trend is clearly in the expected direction, favouring the left ear. However, more important to the above hypothesis, the lower binaural scores persisted in those children 12 years of age and older as well. The left ear score was significantly higher than the both ear score, *t* (19) = 2.66, $p < .02$, and the right ear score was significantly higher than the both ear score, *t* (19) = 3.90, $p = .001$.

Analysis of the Short-form of the ACT

At this point it was thought that perhaps the lower binaural scores, or the supposed story effect could be shown to be limited predominantly to the later stories on the ACT. Since the stories increase in difficulty as one progresses through the subtests, younger subjects might be expected to have more difficulty understanding the longer stories. For this reason, if the later stories may be responsible for the lower binaural scores, then their elimination from statistical analysis might create a test more free of bias. Consequently a shorter version of the ACT was created by totalling each subject's scores for the first three subtests alone. In examining the results of the control sample alone, it was found that the lower binaural scores remained even when only the first three subtests were examined. A t-test showed the left ear condition to be significantly higher than the both ear condition (*t* (35) = 2.39, $p < .03$). A significant difference was also found between the right ear score and the both ear score, once again favouring the right ear (t (35) = 3.68, p = .001). Table 2 shows the means and standard deviations for the three conditions for this shortened test. Furthermore, an ANOVA of the abbreviated test scores revealed no differences between the learning disabled and control groups on the magnitude of the binaural deficit (F (1,71) = 1.01, p = .32). That is, the two groups did not differ any longer on the magnitude of the binaural deficits, and this shortened version, thus, did not discriminate those with deficits from those in the normal population (see Appendix E, Table E-3). A correlation between the shortened version of the test and the full test scores revealed a correlation of r (72) = .95, p < .0001. A correlation between the shortened version of the test with the scores on the last two subtests of the ACT was also highly significant, with r (72) = .87, p < .0001. Both of these findings indicate that the ACT has good internal consistency. Further, if the lower binaural scores in the control group can be attributed to the test, such that the stories which fall on the both ear condition are consistently as a group more difficult for children, it does not appear to be an effect which can be located in the later, more difficult stories, nor limited to only the younger children. Similarly, it is not possible therefore to find an easy solution for eliminating the supposed story effect. In the first place it is difficult, if not impossible, to determine to what extent the lower binaural scores are uniquely attributable to such an effect, and to what extent they might be attributable to the former explanation, that is, that we really do have an abnormally large number of children in the control group with genuine binaural deficits.

If we assume that there is in fact a "story effect" operating to some unknown extent, then one means of correcting it is simply to express each test raw score as a percentage of the mean score obtained by the control group in that condition. For example, a raw score of 78 in the left ear would be divided by the mean left ear score in the control sample (95.8), then multiplied by 100 to give a converted score of 81. This method of correction eliminates the discrepancy between the single ear and both ear mean scores, and corrects the learning disabled group means for the observed story effect (see Table 4).

Table 4

Means and Standard Deviations for the Two Groups Before and After Score Conversion

	Raw scores			Converted scores		
	Left	Right	Both	Left	Right	Both
Learning Disabled	70.6 (21.1)	76.9 (18.6)	67.2 (19.8)	73.6 (22.0)	79.7 (19.3)	74.2 (21.9)
Control Group	95.8 (22.2)	96.5 (18.3)	90.5 (18.0)	100.0 (23.2)	100.0 (18.9)	100.0 (19.8)

T-tests for the learning disabled group after correction still showed significant differences between the left and right ear scores, favouring the right ear (t (35) = 3.40, p = .002), and between the right ear and binaural scores, once again favouring the right ear (t (35) = 3.35, p = .002). An ANOVA (see Appendix E, Table E-4) with the converted binaural deficit as the dependent variable still showed that the learning disabled group had a significantly larger mean binaural deficit than the control group (F (1,71) = 6.06, p <

.02). Finally, a Chi-square comparing the number of learning disabled subjects ($\underline{N}$=9) to the number of control subjects ($\underline{N}$=3) whose binaural deficits exceeded -20% (i.e. whose binaural deficits were clinically significant) was significant, X (1, $\underline{N}$=72) = 3.60, $\underline{p}$ =.058 (see Table 5).

Table 5

Chi-square of the Number of Subjects from Each Group Falling Within the Clinically Significant Range

Count	> -20%	< -20%	Row Total
Learning Disabled	9	27	36 50.0
Control	3	33	36 50.0
Column Total	12 16.7	60 83.3	72 100.0

Selected Learning Disabled Group

Based on teacher reports, a subgroup of the learning disabled subjects was selected using the criteria listed in the Method section. The group selected out by the teachers as having pronounced auditory comprehension problems consisted of 19 of the 36 learning disabled subjects tested, only five of whom actually obtained converted binaural deficits in excess of -20%. The teachers missed completely 4 of the 9 children who did in fact, according to ACT results, have significant deficits in binaural comprehension. For comparison, a Chi-square on the number of subjects with significant binaural deficits revealed no significant difference between the selected learning disabled group and the control group, X (1, N=55) = 3.23, p = .07, although it certainly approached significance and is marginally consistent with the results found for the whole group. Further, the percentage of subjects in this selected group who had significant binaural deficits (26%) was very close to the percentage in the learning disabled group as a whole (25%). These findings suggest that the teachers' accuracy in rating which subjects were likely to have a binaural deficit was no better than chance. In selecting out roughly half of the learning disabled students as likely candidates for an auditory comprehension problem, they still only achieved a "hit rate" of 5 out of 9, or roughly half of the children with binaural deficits, missing the other half completely.

Discussion

As originally hypothesized, a significantly lower mean score was obtained by the learning disabled sample when compared to the control sample, confirming that the ACT is sensitive to difficulties in comprehension found among learning disabled children. The finding of a significant difference between the two groups on the number of subjects with a binaural deficit, as well as on the magnitude of the binaural deficits seems also to support the second hypothesis. However an examination of the means for the control group indicates that they, as a group, were also deficient in the binaural condition.

The finding of a significant advantage within the control group favouring the single ear scores over the binaural score was not expected. Although the percentage of learning disabled subjects found to have a binaural deficit in the present study (41%) is in line with a previous study by Green & Josey (1988) in which 45% of learning disabled subjects displayed significant binaural deficits, these researchers also found a significant difference favouring the binaural score over the higher single ear in their control group. As previously mentioned, this finding could have resulted from either of two possibilities: (1) A selection bias, or (2) A story effect. The selection bias could have resulted from the way subjects were recruited in the present study. Because participation was voluntary and based on parental consent, it might be expected that those parents who had some concerns about their child's learning potential, or about the child's comprehension would be more likely to consent to having their child tested. In fact, in the learning disabled group in the present study, this included almost every child, with one or two exceptions in each school. In the control sample, the result was that instead of a true control group composed of normal children, a larger number of children were recruited who displayed the problems that the ACT is designed to test. Therefore, a random sample of the normal population was not possible.

In his clinical practice, Dr. Green has identified some of the stories as being more difficult for younger children to comprehend and has adopted the practise of making changes in administration so that those difficult stories are randomly distributed across the three conditions. However, there is to date no acceptable order of presentation that will eliminate the story effect, and it remains the responsibility of a clinician skilled in the administration of the ACT to judge how to best alter the administration so as to maintain its validity as a measure of auditory comprehension in all three conditions. Stories can be randomly administered when group data are being collected, so that overall mean scores reflect no bias in the test, but a given child can only be given one order of administration, and that order needs to be determined as being fair.

In the present study, the administration of the test consistently in the order left-right-both would highlight any systematic discrepancy in the difficulty levels of the stories when the overall means for the control group are examined, and this is what was found. Dr. Green has employed a random administration of stories in all of his research to date, which once again masks the story effect. On the basis of the present findings Green has recently undertaken a revision of the ACT in an effort to make it more suitable for younger subjects.

Short-form of the ACT

When testing young children in clinical practice, Green often administers only the first three subtests of the ACT in the belief that the later stories are inappropriate for such subjects (Green, personal communication, 1989). An examination of the first three subtests alone indicates that such a practice is not effective in separating those with deficits from those without deficits. Although a correlation of $r(72) = .87$, $p < .0001$ was found between the shortened version of the ACT and scores on the final two subtests, no significant differences in binaural deficits between the control and learning disabled groups emerge when the abbreviated form of the test is examined. This may have been due to increased variation in the scores on the first three subtests. In any case, it seems that the final two subtests are important in helping to isolate those children with a comprehension problem from those without such a problem. Although they place a load on comprehension that may appear too heavy for the young subject, they contribute an essential element to the ACT's discriminatory power. More important to the present analysis, the story effect remains even if only the first three subtests are used. Significant advantages were found favouring both the left ear and the right ear over the binaural condition for this shortened test.

Analysis Based on Age of Subject

A further examination was undertaken by dividing the subjects into two age groups: those below 12 years of age and those age 12 and above. The subjects were divided in this fashion because Green has found that comprehension reaches its adult level by approximately 12 years of age. Thus if it is hypothesized that the bias occurs because the comprehension level of the younger children was not sufficiently developed, then it would be expected that when divided into the two age groups, the story effect would be present in the younger children only. In fact, the significant advantages favouring the single ears over binaural presentation remained for the older children as well. This indicates that although those children 12 years of age and older score overall in the same range as the adult populations studied, they may still have some difficulty with specific story concepts which are present on some ACT stories.

With the above results in mind, it was determined that in order to correct the bias found in the present study, it would be necessary to directly correct the scores by some form of weighting. The method chosen was to express all subjects' scores as a percentage of the mean control subjects' scores in each ear condition. Although such a correction seems not to take into account the fact that the control group likely contains some children with true binaural deficits, it will, in fact, slightly undercorrect the scores since Green and Josey (1988) found significant advantages favouring the binaural condition over either single ear score. The present correction method assumes that the control group would obtain equivalent scores in each condition, and hence this undercorrection will account for some of the influence of the selection bias as well. Although imperfect, the present method attempts to balance the influences of each problem, to the extent that some meaningful comparisons can be made.

Subsequent analysis still revealed significantly larger binaural deficits in the learning disabled group, and a Chi-square of the number of subjects displaying a binaural deficit remained significant.

Selected Learning Disabled Group

The selected learning disabled group in the present study seems to be different from that in the Green and Josey (1988) study. Firstly, in their study only 18 of the 88 learning disabled subjects (21%) were identified by teachers as fitting the criteria for the selected group. In contrast, the group in the present study consists of 19 of the 36 learning disabled subjects (53%). Clearly, the teachers in the St. Albert School Board are more conservative in their selections. In addition, the rate of successful identification of students found in subsequent testing to have a binaural deficit in the Green and Josey study was 68% in comparison to a success rate of 26% in the present study. Thus, not only are the St. Albert teachers more conservative in their selections, they are also much more accurate in their assessment. One possible explanation for these findings is that the teachers in the St. Albert School Board where Green has carried out much of his research with learning disabled children are much more familiar with the ACT, what it measures and what to look for in a potential subject. Although the selection criteria used by the two groups of teachers are the same, their experience with the ACT is not.

One final result of note in the present study was the finding of a significant advantage favouring the right ear over the left ear in the learning disabled group. This finding is consistent with Green (1983) and is hypothesised to be, firstly, the result of the learning disabled sample having an increased chance of including subjects who have a binaural deficit, and, secondly, because in those subjects who possess a binaural deficit, it is more likely to occur in the longer neural route passing from the left ear to the right hemisphere, then across the corpus callosum to the left hemisphere (Green, 1983).

In summary, the present study supports the notion that learning disabled subjects do possess significantly larger binaural deficits than do normal control subjects. The learning disabled subjects, although matched for IQ, also perform significantly poorer as a group than the control subjects on overall test scores. Further, as expected, there is a significantly larger number of learning disabled subjects than control subjects possessing a clinically significant binaural deficit. This result points to the fact that, although some students in the normal classroom do have this comprehension problem, students who have binaural deficits are much more likely to be labelled learning disabled and find themselves in a special education classroom.

In addition to the above results, a discrepancy was found in the overall scores obtained by the control group such that, when stories are administered consistently in the order left-right-both, there are significant advantages to either single ear over the both ear condition. This finding has not been found in previous studies and likely emerged because of the different method of administration used in this study, as well as to the fact that the control group contains a larger number of subjects who possess binaural deficits than has been the case in previous studies.

Another unexpected finding was the contrast in the success rate of the teachers' selections in this study in comparison to the Green and Josey study. In selecting which subjects they thought fit the criteria of a binaurally deficient student, teacher selections were no better than chance rate, whereas Green and Josey's teachers were much better than chance rate.

Implications

It seems clear that the ACT in its present form, although appropriate for adults, is not as appropriate for children. A revision of the ACT is indicated, and should involve creating a new set of stories that are designed and pretested on children to insure the equivalence of the stories for younger subjects. Certainly some of the concepts on the ACT in its present form are too difficult for young subjects. The stories involving such concepts as terrorism and hijacking, and phrases like "holidaymakers" and "guerilla suspect" are cases in point (see Appendix D).

The present study, although pointing to some problems with the ACT in its present form, adds further support for the existence of the special comprehension problem found in some learning disabled children, as well as some normal children. That this problem has existed undiscovered until quite recently indicates that it is difficult to spot by untrained educators. Work done in Alberta indicates that the subsequent treatment for this problem (the earplug treatment discussed in the introduction) can in some cases lead to dramatic improvements in school and social performance, in rare instances to the point that the student can be moved back to a regular classroom. Educators need to be alert to the potential for such a problem in order to prevent students who could otherwise be aided by the earplug treatment from being misdiagnosed and labelled. It requires that the educator look beyond the superficial problem in learning to the more comprehensive problem which may exist in some of these children.

Although it appears that we can isolate and treat this problem using the ACT, there is at the present time no proven theory about how the problem arises, nor about what can be done to improve teaching methods for those students who demonstrate such a problem, indicating some areas for future research. Perhaps some method of teaching focusing more on experiential learning and less on verbal instruction could be used to further the gains made by the earplug treatment, or perhaps some form of training could be devised to help these students compensate for their comprehension difficulties through increasing attention. Awareness of the problem may in itself provide some measure of relief for these students, whose self-esteem is invariably affected by their learning difficulty.

The present study indicates that the ACT is effective in isolating those subjects with a binaural deficit from those without such a problem, and that its use with children is still justified. However, modification of the ACT is clearly indicated in order to make it more appropriate for the young subject. This work is under way at the present time.

References

Green, E. J. (1985). Interhemispheric coordination and focused attention in chronic and acute schizophrenics. British Journal of Psychology, 24, 197-204.

Green, P. (1978). Defective interhemispheric transfer in schizophrenia. Journal of Abnormal Psychology, 87, 472-480.

Green, P. (1983). Doctoral Dissertation. Unpublished.

Green, P., & Josey, F. (1988). The use of an earplug to increase speech comprehension in a subgroup of learning disabled children. (In press).

Green, P., & Kotenko, V. (1980). Superior speech comprehension in schizophrenics under monaural versus binaural listening conditions. Journal of Abnormal Psychology, 89, 399-408.

Green, P., & Kramer, E. (1984). Auditory Comprehension Test. Edmonton: Green and Kramer.

Hallett, S., & Green, P. (1982). Possible defects of interhemispheric integration in children of schizophrenics. Journal of Nervous and Mental Diseases, 171, 421-425.

Hatta, T., Yamamoto, M., & Kawabata, Y. (1984). Functional hemispheric differences in schizophrenia: Interhemispheric transfer deficit or selective hemisphere dysfunction? Biological Psychiatry, 19, 1027-1036.

Hunter, M., & Green, P. (1985). Abnormal interhemispheric integration and schizophrenia. International Review of Applied Psychology, 34, 349-362.

Katz, J., & Wilde, L. (1985). Auditory and perceptual disorders in children. In Katz, J. (Ed). Handbook of Clinical Audiology. Baltimore: Williams and Wilkins.

Neale, M.D. (1966). The Neale Analysis of Reading Ability. London: MacMillan Education.

Reid, D.K. and Hresko, W.P. (1981). A cognitive approach to learning disabilities. New York: McGraw-Hill.

Wechsler, D. (1974). Manual for the Wechsler Intelligence Scale for Children (revised). New York: The Psychological Corp.

Wechsler, D. (1981). Manual for the Wechsler Adult Intelligence Scale (revised). New York: The Psychological Corp.

Appendix A

The Auditory Comprehension Test: Supplementary Information.

Initial Adult Standardization Sample

The ACT was standardized on a group of 52 adult subjects recruited from the staff of Alberta Hospital Edmonton, including 44 females and 8 males. The overall mean verbal IQ, estimated from the vocabulary subtest of the WAIS-R, was 101.6. The mean age of the sample was 31.4 years. The scores of this group on the ACT showed no significant difference between the left, right, and binaural scores. The mean ACT scores (out of 160) were:

Left ear recall = 100.21 (s.d.= 16.17)
Right ear recall = 101.23 (s.d.= 13.83)
Binaural recall = 101.52 (s.d.= 13.31).

From this the mean recall score was calculated to be 100.99 (s.d.= 13.31).

It can be seen from the mean IQ that the normal sample conforms closely to the general population in intelligence. Their scores on the ACT also conform nicely to a normal distribution with a mean of 100.99 and a standard deviation of 13.31. Of the 52 normal subjects, 18 scored within one standard deviation above the mean, and 19 scored within one standard deviation below the mean. Further, seven subjects were between one and two standard deviations above the mean and six occupied this position below the mean. The remaining two subjects scored more than two standard deviations above the mean.

<u>Equivalence of the sets of stories</u>

To check the equivalence of the sets of stories of the ACT the stories in each subtest were randomly arranged and administered to 9 normal subjects under binaural conditions only. Since no significant differences emerged from this administration, 52 additional subjects were presented the stories in the standard left-right-both fashion. Their results on each individual story are presented below. The standard presentation results in pairing all .1 stories with .4 stories, all .2 stories with .5 stories and all .3 stories with .6 stories. The results indicate extremely small ranges of difficulty within each subtest, with the difference between the easiest and most difficult story in each subtest for the normal sample being as follows: Test A, 0.79, Test B, 0.22, Test C, 0.29, Test D, 0.80, and Test E, 0.64.

Table A-1

Mean Scores and Standard Deviations for Each Story on the ACT Obtained by the 52 Normal Control Subjects

		Story Number					
		.1	.2	.3	.4	.5	.6
Test A	Mean	8.15	8.25	9.27	9.02	8.19	7.96
	(S.D.)	(1.45)	(1.31)	(0.08)	(0.99)	(1.59)	(1.34)
Test B	Mean	7.23	8.69	9.08	8.86	7.62	7.19
	(S.D.)	(1.67)	(1.10)	(1.07)	(1.43)	(1.33)	(1.36)
Test C	Mean	9.62	10.37	11.5	10.77	9.77	8.73
	(S.D.)	(3.13)	(2.03)	(2.01)	(1.90)	(1.86)	(2.24)
Test D	Mean	10.48	11.62	13.13	11.83	10.58	8.38
	(S.D.)	(3.45)	(3.08)	(2.45)	(2.81)	(2.69)	(3.22)
Test E	Mean	12.08	13.0	14.04	13.15	12.63	11.83
	(S.D.)	(3.92)	(3.40)	(4.52)	(3.81)	(3.76)	(3.74)

Note. From Green (1983), Unpublished Dissertation. Reprinted by permission.

Classifying abnormal binaural deficits

The identification of subjects as having an abnormal binaural deficit has evolved through trial and error using the normal standardization sample. For the normal sample, the average binaural deficit was -3.165% (s.d.=9.66). The formula used to calculate the binaural deficit was:

$$([B-HS]/B) \times 100, \text{ where}$$

B= score from both ears,

HS= highest single ear score.

The limits for the normal sample, when arbitrarily set at +18% and -20% misclassified only one of the 52 normal subjects. It is the latter limit that is of interest here since scores below this point are indicative of a binaural impairment and warrant further testing using an earplug.

Appendix B

Results of evaluation of earplug effects based on parents' reports.

PART B

BRIEF SUMMARY OF RESULTS OF EVALUATION OF EAR PLUG EFFECTS BASED ON PARENTS' REPORTS

Prepared by Paul Green Ph. D. on the basis of information provided by parents in response to a questionnaire sent to parents by Frank Josey (Director of Student Services). Parents were asked to report on whether or not their children were wearing earplugs at the time of the survey and, if so, whether the earplugs seemed to be of benefit.

1. Number of parents' providing information = 16

2. Number of children still wearing earplugs at the time of this follow-up survey

   13 out of 16.

3. Mean age of children wearing earplugs. = 10.5 yrs.

4. Mean number of hours earplugs being worn per day = 8.73 hours.

5. Mean number of months earplugs had been worn = 6.7 months.

6. In response to the question "Do you think that since wearing the earplug your child's progress in school has improved, stayed the same or got worse?"

   10 replied IMPROVED
   1 replied SAME
   2 replied WORSE
   3 replied NOT SURE

7. In response to the question "Do you think your child is helped by the earplug?"

   9 parents replied YES
   1 parent replied NO
   5 replied NOT SURE

8. In response to the question "Have any school staff told you whether they have noticed any change in your child as a result of the earplug?"

TEN parents replied YES

In each case, improvement was reported, usually in a statement such as "Understands better what is said." (See attached teachers' reports.)

9. COMPREHENSION PROBLEM RATING SCALE: CHANGE SINCE EARPLUG WORN.

On a measure of change in speech comprehension problems, the parents' ratings of change after the earplug showed:

a. Improvement on 117 out of 252 items on which problems had been present before earplugs were fitted. That is, improvement occurred in 46% of 252 problem items initially reported.

b. The number of problem items that stayed the same was 125 (49% of problem items initially reported.)

c. The number of problem items for which deterioration was reported after wearing the earplug was 10 (3.9% of 252 items).

10. BEHAVIOR PROBLEM CHECKLIST: CHANGE SINCE EARPLUG WORN.

On a separate measure of general behaviour problems, parents' ratings of their children before the earplug reached a total of 386. The parents' ratings after the earplug dropped to 305, showing that the parents, as a whole, believe that their children display fewer behaviour problems than before the earplug.

11. IMPROVEMENT SPECIFIC TO COMPREHENSION PROBLEMS.

The degree of improvement in their children reported by parents was greater on the Comprehension Problem Rating Scale than on the more general Behaviour Problem Checklist. Also, within the Comprehension Problem Rating Scale, most of the improvement was reported on items directly related to speech comprehension rather than on items only indirectly associated with comprehension . (e.g. "Mishears what I say" compared with "Thinks I am angry when I am not.")

These results suggest that the earplug specifically improves speech comprehension and has less or no effect on aspects of behaviour unrelated to the understanding of speech.

CONCLUSION:

These preliminary results suggest that, in suitable cases, an earplug produces significant improvement in the understanding of speech not only in recalling stories under test conditions but also in everyday life. In most cases, improvement in school progress is reported by parents since their children have worn an earplug. Teachers' reports (as reflected in parents' questionnaire responses) support the beneficial effects of an earplug in aiding speech comprehension in most cases.

Appendix C

Consent forms sent out to parents for permission to test children.

Dr. Scott Sellick,
Clinical Psychologist
& Adjunct Professor,
Lakehead University,
Thunder Bay, Ontario.

April 4, 1989

Dear Parent or Guardian:

A research proposal was presented to the Lakehead Board of Education in December 1988 and Mr. Curt McMahon, Superintendent of Special Services, informed us in February that permission had been granted for us to proceed with the project. The proposal has also been reviewed by the Senate Research Committee at Lakehead University and funding has been granted to the principle investigators, myself and Dr. Margaret Sellick, assistant professor in the Psychology Department.

We need two groups for our study - a group of identified learning disabled students, and a group of mainstream students so that we can compare the learning disabled students' results with those of students who have not been identified as having learning difficulties. We approached the principals and special education teachers of the appropriate schools and were granted permission to work with their students. We are now asking for the consent of parents or guardians.

We have received permission from the parents of learning disabled students to work with their children and we are now seeking permission to work with your child, a student who will serve as a comparision (a control subject) for the student who has a learning difficulty. The attached sheet briefly explains what we are asking and describes what will be expected of your child. Please consider helping us in our study and return the signed sheet to the school. Your child may turn it in to the classroom teacher.

Please call me at the university (343-8441) and leave a message for me to get back to you if you have any questions or wish to discuss how you may receive feedback concerning your child's performance. Research findings will be kept confidential but will be shared with the classroom teacher and principal so that your child's efforts will be of value not only to us and to the learning disabled students, but to your child's classroom teacher as well (thereby having a potential benefit for your child). I'd be pleased to return your call.

Thank you for your time and your consideration.

Sincerely,

S. M. Sellick, Ph.D., C.Psych.

PERMISSION FOR TESTING OF STUDENT'S MEMORY AND COMPREHENSION

Dr. Scott Sellick and Dr. Margaret Sellick of Lakehead University's Department of Psychology have approached the Lakehead Board of Education and asked that permission be granted for them to visit six of our schools and test 40 learning disabled students and 40 other chosen students who are of the same age, sex, and general level of intelligence as the forty learning disabled students (a matched control group). Their written research proposal has been approved by the Board Office and by the principal of your child's school. As parents or guardians of these students, your permission is also necessary before testing can begin with your child.

Your child will be tested by a graduate student in clinical psychology and will be supervised by Dr. S. Sellick. The testing will take 20 - 30 minutes and we expect that the student will be absent from the classroom for less than 45 minutes. During testing the child will be wearing ear-phones (head-phones) so that they will be able to hear short stories that have been pre-recorded on an audio-tape. After listening to each story, the tape-recorder will be turned off and the student will be asked to recall as much as can be remembered.

In addition, a short test (10 minutes) to estimate your child's level of intellectual functioning will be administered, so that the children in the study can be matched with each other and correct comparisons can be made. As with the memory and comprehension test, all information will remain confidential.

Similar work has been done with learning disabled and non-learning disabled children in Alberta since 1986 and has been well received by parents and teachers for it has provided valuable information concerning the student's abilities and his or her learning problems. For some it has resulted in a significant change in the understanding of the child's problem and in the ways in which they are taught.

The information that will be gathered will be submitted in document form to the teachers, principals, and Board authorities and perhaps most importantly, the researchers will be available to speak with parents of students at the completion of the project. Necessary arrangements would be made through the office of your child's school.

I will allow my child to be tested using the procedure described above (comprehension & memory and intellectual functioning estimate) and understand that such testing will take place in April, May or June of this year. I understand that this project has been approved by the Superintendent of Special Services and the principal of my child's school and is to be supervised by Dr. Scott Sellick, registered psychologist.

NAME (please print) ____________________ DATE ____________________

SIGNATURE ____________________

Appendix D

The ACT test answer form

Test Answer Form

Subtest A 22 word stories

10.1 Kitten
L The children () were watching () a policeman () climbing () up a tree
R (). He was rescuing () a white () kitten () that was sitting () on a
B branch().
[ ]

10.2 Channel
L A 12 year old () boy () from Washington () broke () a world record ()
R on Saturday (). He swam across () the English Channel () in four ()
B hours ().
[ ]

10.3 Birthday
L Kathy's () father () gave her() a present () for the birthday (). She
R had expected () some chocolates () but in the box () there was () a
B dress ().
[ ]

10.4 Arrest
L A 15 year old () girl () stole () some jewelry () from a department ()
R store (). A detective () followed her () into the street () and
B arrested her ().
[ ]

10.5 Zoo
L The children () spent an hour () looking at () animals () in the
R Zoo (). One gorilla () reached out () of his cage () and touched ()
B the teacher ().
[ ]

10.6 Charity
L Twenty-seven () Canadian () children () collected () over $1000.00 ()
R for charity (). The money was sent () to a school () for the blind ()
B and the handicapped ().

Test Answer Form

Subtest A 22 word stories

10.1 Kitten
L The children () were watching () a policeman () climbing () up a tree
R (). He was rescuing () a white () kitten () that was sitting () on a
B branch().
[ ]

10.2 Channel
L A 12 year old () boy () from Washington () broke () a world record ()
R on Saturday (). He swam across () the English Channel () in four ()
B hours ().
[ ]

10.3 Birthday
L Kathy's () father () gave her() a present () for the birthday (). She
R had expected () some chocolates () but in the box () there was () a
B dress ().
[ ]

10.4 Arrest
L A 15 year old () girl () stole () some jewelry () from a department ()
R store (). A detective () followed her () into the street () and
B arrested her ().
[ ]

10.5 Zoo
L The children () spent an hour () looking at () animals () in the
R Zoo (). One gorilla () reached out () of his cage () and touched ()
B the teacher ().
[ ]

10.6 Charity
L Twenty-seven () Canadian () children () collected () over $1000.00 ()
R for charity (). The money was sent () to a school () for the blind ()
B and the handicapped ().

Subtest B 26 word stories

10.1 Christmas
L The presents () were opened () on Christmas day.() Peter () got a
R bicycle () from his father () and Annie () got a video game () from
B her great-uncle () in Scotland ().
[ ]

10.2 Holiday
L John () and Mary () went on holiday () with their parents (). In the
R aeroplane () they sat () near a window () and looked down () at the
B ships () in the sea ().
[ ]

10.3 Classroom
L Michael () was sitting () at the back () of the classroom (). When
R the teacher () turned around () and wrote () on the blackboard () he
B took a bite () from his sandwich ().
[ ]

10.4 Dog Show
L Janet () entered () her terrier () in a dog show (). The first prize
R () went to a bull dog () with no tail () but Janet's dog () won ()
B the second prize ().
[ ]

10.5 Squirrel
L A squirrel () came down () form an oak tree () into the garden () and
R found () some peanuts (). NOw the grey squirrel () comes back ()
B every day () for more food ().
[ ]

10.6 Circus
L Roger () went to the circus () with his mother () and his sister () on
R sunday (). They saw a monkey () on a trapeze () and a dog () riding
B () a horse ().
[ ]

Subtest C   33 word stories

15.1   Wolves

L   Young () animals () play games () in order to prqctice () skills ()
R   which they will need () to survive (). Packs () of young wolves ()
B   sometimes capture () a deer () but instead of () killing it () they
[ ]   allow it () to escape ().

15.2   Baby

L   Jack () was going () to school () when he saw () a baby carriage ()
R   rolling () toward the road (). Dropping () his bag () he ran () to
B   save the baby () from rolling () into the path () of a speeding ()
[ ]   truck ().

15.3   Puppies

L   When Roy () came home () he found () a basket () full () of clothes ()
R   on the porch (). When he tool it () into the house () he heard () a
B   squeak (). Inside the clothes () there were two () black () puppies
[ ]   ().

15.4   Camping

L   Carol () and Doug () were camping () near a river (). While they were
R   cooking () their supper () they heard () a splash (). A fisherman ()
B   had fallen () out of his boat (). Doug () waded out () and pulled him
[ ]   () ashore ().

15.5   Bears

L   Car drivers () and motorcyclists () had stopped () on the roadside ()
R   in the park (). They were watching () a mother () bear () and her
B   three () cubs () which had come () from the forest () to eat ()
[ ]   berries () in the ditch ().

15.6   Strike

L   Many () holidaymakers () were disappointed () when they arrived () at
R   the airport () this weekend (). Passengers () on flights () to
B   Florida () and Spain () were told () that the air traffic ()
[ ]   controllers () had gone on strike () for higher pay ().

Subtest D 45 word stories

20.1 Fishermen

L Three () fishermen () were stranded () when their engine () broke down
R () in the atlantic (). Air Force () Helicopters () searched () for a
B week () but were unable to find them (). After 90 days () two ()
[ ] survivors () were washed ashore () in their boat (). They had been
living on () fish () rain () and seawater ().

20.2 Kidnap

L A month ago () a German () businessman (), who was staying () an a
R hotel () in Rome () was kidnapped (). This week () his wife () flew
B to () Italy () and announced () in a television () interview () that
[ ] she would pay () the million dollar () ransom () if her husband () was
returned to her () unharmed ().

20.3 Caffeine

L The drug () caffeine () which is present () in coffee () can lead to
R () loss of sleep, () headaches () and depression (). These symptoms
B () can last () up to 2 days () after the last drink () of coffee ().
[ ] Caffeine () is also found () in chocolate () some cola drinks (),
headache tablets () and frozen () puddings ().

20.4 Racquetball

L Scientists () at the University of () Toronto () have been studying ()
R hundreds () of eye () injuries () in racquetball players (). In 70
B cases () the ball (), travelling () at 100 mph () had hit the eye
[ ] directly (), causing damage () requiring a week () in hospital ().
The players () had not been wearing () protective () glasses ().

20.5 Prime Minister

L An Austrian () man () was arrested () when he was banging () on the
R Prime Minister's () door () with a rock () on Thursday (). He was
B protesting () about being unemployed () and homeless (). The judge ()
[ ] found him () guilty () of causing () a public () nuisance () and
sentenced him () to one month () in prison ().

20.6 Pope

L While escaping () from detectives () a guerilla () suspect () was hit
R () by a car (). He told () security () forces () that there was a
B plot () to kill () the pope () on his tour () of El Salvador (). Then
[ ] he handed over () the passports () of 18 sharpshooters () who had
entered () the country ().

Subtest E 56 word stories

25.1 Hijack
L The pilot () of a hijacked () Libyan () D.C. 10 () airliner () was
R told () to fly () to Malta (). When the plane landed () in Paris ()
B to refuel (), a blizzard () grounded the aircraft () for 24 hours ().
[ ] Eleven () children () and one woman () were allowed to leave () the
plane (). Minutes later (), the hijackers () surrendered () after a
surprise () assault () by an anti-terrorist squad ().

25.2 Railway
L A murder () suspect () drove a () stolen () red () convertible () at
R high speeds () after escaping () from police () on Saturday (). It
B sped toward a railway crossing () at the same time () as an express ()
[ ] train (). The engineer () braked () but the track () was icy (). The
car () was thrown () across the road () and stopped () in the flower
bed () of a children's () hospital ().

25.3 Fire
L Many people () watched () the Fire Department () using ladders () for
R the rescue () of office () workers () from a burning () building () on
B McDonald Street (). As the fire chief () helped () an injured () man
[ ] () into an ambulance () an explosion () threw him () to the ground ().
A woman () who lit () a cigarette () near a damaged () gas pump () was
accused () of starting the fire ().

25.4 Airbrakes
L The co-pilot () of a medium-sized () plane () caught sight () of the
R airfield () when he noticed () that he was fjying () too low (). He
B had to act quickly () to avoid () collision () with a skyscraper ().
[ ] He banked () right () sharply () and circled () the airport ().
Sighing () with relief () he pulled () the lever () to lower () the
wheels () and touched down () safely ().

25.5 Bank
L Mary Robinson () of south () Calgary () a bank () manager () arrived
R first () on Friday () morning (). In the entrance () were three ()
B men () wearing masks () and carrying () shotguns (). They forced her
[ ] () to open the safe () and then they tied () her hands (). At the
rear exit () the police () stopped () the bank robbers () while
questioning () the driver () of the getaway car ().

25.6 Storm
L Expecting () the sunny () weather () to last all day (), a group () of
R inexperienced () climbers () proceeded () to the top () of the
B mountain (). Though they sheltered () behind a wall (), they were
[ ] cold () and frightened () when a storm () arose (). For two () hours
() they suffered () wind and rain () and they came very close () to
being struck () by lightning () near the peak ().

Appendix E

ANOVA tables.

Table E-1

ANOVA of the Overall Average Score by Type of Subject (Learning Disabled or Control)

Source	Sum of Squares	DF	Mean square	F	sig. of f
Main effects	9308.5	1	9308.5	25.96	.001
Type	9308.5	1	9308.5	25.96	.001
Explained	9308.5	1	9308.5	25.96	.001
Residual	25102.2	70	358.6		
Total	34410.7	71	484.7		

Table E-2

ANOVA of the Magnitude of the Binaural Deficits by Type of Subject

Source	Sum of Squares	DF	Mean square	F	sig. of f
Main effects	1217.7	1	1217.7	5.87	.018
Type	1217.7	1	1217.7	5.87	.018
Explained	1217.7	1	1217.7	5.87	.018
Residual	14515.7	70	207.4		
Total	15733.4	71	221.6		

Table E-3

ANOVA of the Abbreviated Binaural Deficits by Type of Subject

Source	Sum of Squares	DF	Mean square	F	sig. of f
Main effects	391.0	1	391.0	1.01	.32
Type	391.0	1	391.0	1.01	.32
Explained	391.0	1	391.0	1.01	.32
Residual	27231.3	70	389.0		
Total	27622.2	71	389.0		

Table E-4

ANOVA of the Corrected Deficits by Type of Subject

Source	Sum of Squares	DF	Mean square	F	sig. of f
Main effects	1127.2	1	1127.2	6.06	.016
Type	1127.2	1	1127.2	6.06	.016
Explained	1127.2	1	1127.2	6.06	.016
Residual	13027.3	70	186.1		
Total	14154.5	71	199.4		