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ABSTRACT

A study investigated whether a correlation exists between the degree and nature of left-brain laterality and specific reading and spelling difficulties. Subjects, 50 normal readers and 50 reading disabled persons native to the island of Bornholm, had their auditory laterality screened using pure-tone audiometry and dichotic listening. Results indicated the existence of a significant correlation between the degree and nature of left-sided laterality and reading/spelling difficulties. Results also indicated that auditory laterality for men with reading and spelling difficulties differs from auditory laterality for women with reading and spelling difficulties. (RS)

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Diagnosing dyslexia:
THE SCREENING OF AUDITORY LATERALITY

Summary

For decades researchers have been aware of the possible correlation between uncertain laterality and specific reading and spelling difficulties (developmental dyslexia). Unfortunately the significance of auditory laterality has often been overlooked.
In this article the author documents the existence of a significant correlation between the degree and the nature of left-sided laterality and reading/spelling difficulties. Furthermore it appears that auditory laterality for men with reading and spelling difficulties differs from auditory laterality for women with reading and spelling difficulties.

A study has been carried out using 50 normal readers and 50 reading disabled (RD's) on the island of Bornholm in the Baltic Sea. The cultural, educational and socio-economic differences on Bornholm are so relatively limited that they have not been considered here.

Premises

For almost an entire century certain groups of educators and psychologists have been aware of the question "How does a child's handedness influence the rate at which reading development takes place?".

It is an accepted fact that a greater relative number of left-handed persons have reading and spelling difficulties than do right-handed persons. Therefore, some sort of connection must exist between handedness and language development as documented by Mamen (1987) among others. However, the connection is so difficult to map out that most educators have chosen to ignore it.

The work underlying the following material is based on a hypothesis concerning a certain correlation between the degree of laterality and reading development as a basis for efforts to determine auditory laterality.

Laterality is a broader term for human asymmetrical skills: in other words the differences existing between each half of the body and each side (hemisphere) of the brain.

In general the left side of the brain controls the right side of the body and vice versa.

When the right hand manipulates something, it is primarily controlled from the left side of the brain. When the left ear perceives a sound, it is first registered on the right side of the brain. A visual impression in the right field of vision is decoded in the visual cortex on the left side of the brain.

Around two-thirds of all persons have an advantage for all such functions on the right side of the body and therefore sensual and control-related dominance in the left hemisphere.

There is, however, no clear question of either/or, but whether sensual impressions or functions are predominant in one or the other hemisphere.

A very small percentage have a corresponding preference for all functions on the left side of the body and corresponding right-hemisphere dominance.

In nearly thirty percent of the population, the dominances are more uncertain (Springer & Deutsch 1981; Geschwind & Galaburda 1987).

The human brain, under certain stress-related influences (such as when a poor speller is forced to write down his/her answers), can even decide to alter its dominance.

A brain-dominance model (radically simplified) is illustrated below in fig. 1 in which H, M and S represent hearing, motor and sight respectively; capital letters indicate dominance and small letters indicate non-dominance (Johansen 1984). One result of this simplification is that motoric dominance is considered as one dimensional, which is hardly the case. For instance a person can be left-legged and right-handed or left-handed in fine motor movement and right-handed in gross motor movement. To a certain degree, motoric dominances appear to be connected to muscle groups via neuron clusters.

Fig. 1

Aberrant dominances can apparently come into conflict with the general linguistic dominance where the form of language including speech (phonology), spelling and reading of letters, (or more generally the entire sequential processing), belongs on the left side of the brain, while cadence, stress, intonation and rhythm (prosody) belong on the right side of the brain (Johansen 1988).

In times past, it was common practice in many schools to force all children to write with their right hands based on the notion that left-handedness was primarily an impractical, bad habit.

Later we wised up (but not enough) and let children uncritically choose for themselves the hand they wanted to use for writing. Some children were particularly slow in choosing hands, and some even chose the wrong one.

During the course of the last couple of years, I have found four left-handed boys in the 12 to 14 year-old age group without any form of familiar left-handedness (out of a group of approximately five hundred RD's). All four boys kick penalty kicks with the right leg, and possess right-ear and right-eye advantage. All four boys have at one point in time between the ages of 2 and 4 seriously burned or scalded their right arm or hand!
Wouldn't it have been a good idea to have forced these four boys to use their right hand for writing instead?

Given the above reservations, reasonable agreement exists concerning the phenomenon of handedness. However, agreement regarding visual and auditory advantage is slightly more difficult to uphold.

In regards to the visual aspect, one can possess both eye preference and field-of-vision preference. Many batteries of tests are available for making such determinations. For a simple eye-preference test, have the pupil to be tested look through a cardboard tube and grip it with both hands with outstretched arms. The pupil should look with both eyes open through the tube toward the researcher's face.
Field-of-vision preference is more difficult to determine, but testing material, which includes the tachistoscopic presentation of visual stimuli (using a personal computer for example) can be used for this purpose.

A simple, combined analysis of the simplified dominance model (fig. 1) shows that the following possibilities for deviations from the "normal" picture apparently exist (fig. 2).
This is true for persons whose primary language dominance (sequential coding) is in the left hemisphere, which is estimated to be 97 to 98 % of all persons (including more than half of all left-handed persons).
For the small percentage of people whose language dominance is in the right hemisphere, corresponding but opposite models can be made (Johansen 1984).

Fig. 2

Such "model-plane flying" can obviously seem rather theoretical. The exciting factor in all of this, however, is that combined tests for auditory, motoric and visual dominance show that all types do in fact exist. Especially when the existence of a clear correlation between the degree and the nature of auditory laterality and reading development is demonstrated.

Method

Around the time of their fourth birthday, most children demonstrate right-ear advantage (REA) towards linguistic stimuli. Undoubtedly this correlates with the specialised processing of auditory input by the brain. Of course it is a question of degree of right or left ear advantage; but the differences are more than just matters of curiosity.

This study has included the screening of auditory laterality in two rounds. First using pure-tone audiometry and second using dichotic listening (Johansen 1990).
For the audiometric study, a finely-tuned audiometer with R+L function has been used. This means that sound can be sent to both ears simultaneously (binaural testing).
Using pure-tone audiometry, normal, monaural threshold measurements (one ear at a time) have been performed.

The French ear specialist, A.A. Tomatis, has suggested that a hearing curve as shown in fig. 3 should be considered as optimal for children who are developing their language.
The curve is based on an average for a wide range of individuals who function well linguistically and musically.
It should be perceived as a contrast to the commonly utilized 20 dB curve (developed by telecommunication engineers as being the minimum level at which an experienced language user can carry on a telephone conversation without problems).

Deviations from this optimal curve are more or less significant for an individual's command of language since language coding is also contingent on the participation of other factors such as context, memory, etc.

Fig. 3

After carefully measuring thresholds, two rounds of binaural pure-tone audiometry (BPTA) were carried out.
The described procedure provided reliable measurements when repeated.
The pupil sat in front of the tester with his/her back turned towards the tester. At this time, the following instructions were issued:

> A sound will now be sent to one ear at a time or both ears at the same time. Indicate which ear receives the sound by raising one hand or both hands when the tone starts and when lowering it/them when it stops. Use the hand which corresponds to the side on which you hear the tone. Keep your hand up for as long as the tone lasts. When the tone stops, put your hand or hands down.
>
> There is no system in the order of the tones. You may receive a tone ten times in one ear and none at all in the other ear. Perhaps the tones will change constantly or be sent to both ears all the time. Therefore it is important to listen closely.

The audiometer was positioned at 20 dB and the tester randomly shifted between R, L and R+L.
The tests were performed in the following order: from 1000 Hz and downward to 125 Hz. Subsequently from 1000 Hz and upwards to 8000 Hz.
Only reactions for R+L were recorded (see the example below).

BPTA at 20 dB: O—⊠—X—O—X—⊠—⊠—O—X—X—X

The right was recorded six times (R1=6). The left was recorded 8 times (L1=8).

During the second round of BPTA, the pupil received the same instructions as during the first round. A message that the sounds would be fainter than during the first round was added.

The audiometer was positioned at R+L and at -10 dB. The volume was thereafter raised in intervals of 5 dB, and each level was held for 4 seconds. At the first reaction of the pupil, "O, X or ⊗" was recorded. (R: O, L: X, R+L: ⊗).

The frequencies were thoroughly tested in the same order as given for the first round see the example below:

BPTA, threshold: O—⊗—X—O—X—O—⊗—O—X—X—X

The right was recorded 6 times (R2=6). The left was recorded 7 times (L2=7).

Based on these two BPTA tests, a BPTA R-L score was calculated.

R=R1+R2=6+6=12; L=L1+L2=8+7=15. R-L score=(R-L)x100/(R+L).

$$\frac{(12-15) \times 100}{(12+15)} = \frac{-3 \times 100}{27} = -11$$

A R-L score can lie anywhere between -100 (decided L-ear advantage) and +100 (decided R-ear advantage).

In contrast to the BPTA test described above, another binaural method of examination, **dichotic listening (DL)**, is gradually becoming more widespread.

Dichotic listening consists of the monitoring of linguistic sounds (words, syllables, non-words), which are sent simultaneously to both ears. The SSW-test prepared by Jack Katz is such a test. Persons desiring a thorough, theoretical background for DL ought to read Kenneth Hugdahl's book (Hugdahl 1988).

To carry out this type of research programme, a dichotic listening test was used consisting of single words and pairs of words as shown below.
The test is recorded on a magnetic tape which also contains the necessary instructions.
After a male voice has given the instructions, the voice of a young girl pronounces the test words. In so doing, the test words are presented more clearly and a variation is achieved. The test includes single words and pairs of words as follows:

A: 20 single words sent to the right ear only. Nothing to the left ear.

B: 20 single words presented to the left ear only. Nothing to the right ear.

C: 20 pairs of words presented to the right and left ears simultaneously but with a request that only the words heard by the right ear be repeated.

D: 20 pairs of words presented to the right and left ears simultaneously but with a request that only the words heard by the left ear be repeated.

E: 20 pairs of words presented to the right and left ears simultaneously, but with a request that as many words as possible be repeated.

The total number of correctly repeated words heard by the right and left ears respectively are recorded during the test and used for calculating the **dichotic R-L score** using the same calculation method as before.

$$\text{R-L score} = (R-L) \times 100 \;/\; (R+L).$$

In this case, a negative R-L score also demonstrates L-ear advantage and a positive R-L score demonstrates R-ear advantage.

Examination group and control group

All participants in the examination group were volunteers who professed reading and spelling problems. The study group included 19 female and 31 male participants from the ages of 9 to 23. All the participants possessed reading skills which would classify them as dyslexics. No intelligence tests were made; everyone in the examination group was judged to possess normal intelligence.

The relatively modest predominance of male participants in this study is related to that fact that subjects had volunteered. In daily practice, cases of males with reading and spelling difficulties appear with considerably greater frequency.

The control group consisted of normal readers between the ages of 8 to 25. Forty of them were students with an average age of 14 from two seventh grade classes. The control group included 25 female and 25 male participants.

All those examined are native to the island of Bornholm in the Baltic Sea where the cultural, educational and socio-economic differences are minimal.

Results

Of the participants in the control group, over 80 % had positive scores for both the BPTA-test, and the DL.

There did not seem to be any obvious age or sex variation. On the other hand though, a variation related to handedness appeared which supports the usual results in which some left-handed persons also have other advantages for the left side.

Among the RD group, the picture is much more mottled. This indicates that a significantly greater spread in test results exists than is the case for the normal reader group.

When testing monaural thresholds, a typical audiogram which appears is one in which the left ear shows greater sensitivity than the right ear over a large frequency range. Though the difference is not particularly great, it is distinct. Fig. 4 shows a typical curve for a right-handed dyslexic, in this case a thirteen-year-old girl.

Fig. 4

For BPTA and DL, no direct correlation between scores can be established. However a particularly great spread exists (as shown in the table in fig. 5), in which the subjects are divided into four groups corresponding to the test results established using BPTA and DL. Notice that both of the RD boys in group 1 in figure 5 are left-handed.

Fig. 5

The distribution can also be illustrated with a coordinate system in which the X-axis represents scores from BPTA and the Y-axis represents scores from DL. The three figures in each field represent the percentage of total, male and female respectively.

Fig. 6

In corresponding tables for the control group, there are over 80% in group 1: positive scores in BPTA and DL.
Each individual's auditory laterality profile can be illustrated as in fig. 7. Here normal readers for the most part lie within the "envelope" indicated while RD's receive greatly divergent readings.

Fig. 7

Discussion

Screening for auditory laterality including BPTA and DL reveals a highly distinct deviation between the results for normal readers and those for RD's (regardless of sex and age, but to a certain degree dependent on handedness). Past experience showing a correlation between divergent laterality and slow reading development are therefore correct. However far too little awareness has been shed on the phenomenon of auditory laterality. Therefore, auditory laterality must be studied using both BPTA as well as DL before a reliable picture of how RD's differ from normal readers can be revealed.

With total or partial left-ear advantage (LEA), phonemes or portions of phonemes will be perceived through the left ear, while other portions will be perceived through the right ear. Due to the neural construction of the auditory system in which the contralateral auditory input arrives at the auditory nerve's cortical endpoint prior to ipsilateral input and (in the case of the left hemisphere at least) provokes a stronger reaction, total or partial left-sided auditory laterality can mean that portions of certain phonemes are mixed obscuring the difference between b and p or d and t, for example.
We know that RD's to a great degree have early and continuous auditory problems which are especially related to phoneme analysis and phoneme discrimination.
Through auditory laterality studies of the RD's, perhaps we will acquire greater understanding of the specific nature of the problems and in so doing a greater understanding of how the overall special education programmes can be supplemented with goal-oriented stimulation of the auditory system (Johansen 1984; 1988).

In his dissertation, Steen Larsen has documented how auditory laterality and reading development correlate in various studies (Larsen 1989).

At a lecture in September 1990 at the European Dyslexia Conference, Fred Warnke presented a range of measurements of auditory laterality which to a great degree are in accordance with the study referred to here (Warnke 1990).

In our search for possible causes of dyslexia and our attempts at remedying it, we are generally quite bound by traditional solutions even though the latest neuropsychological research ought to prompt more unconventional initiatives (Johansen 1989).
A basis for unconventional approaches is found in the writings of such individuals as Marian C. Diamond:

> Perhaps the single most valuable piece of information learned from all our studies is that structural differences can be detected in the cerebral cortices of animals exposed at any age to different levels of stimulation in the environment (Diamond 1988).

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Fig. 1

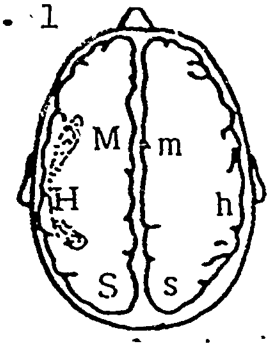


Fig. 2

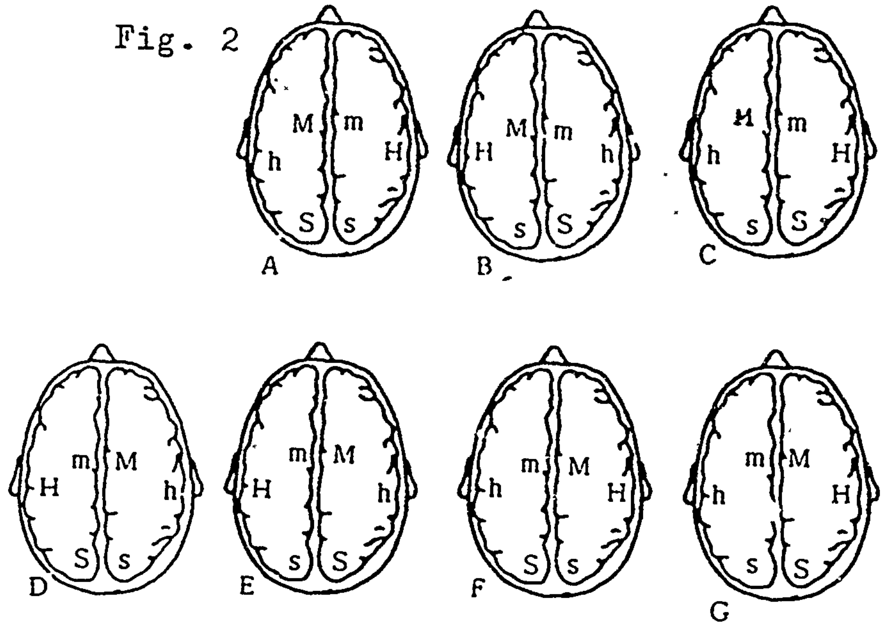


Fig. 3.
MONAURAL THRESHOLDS. The A.A. Tomatic curve:

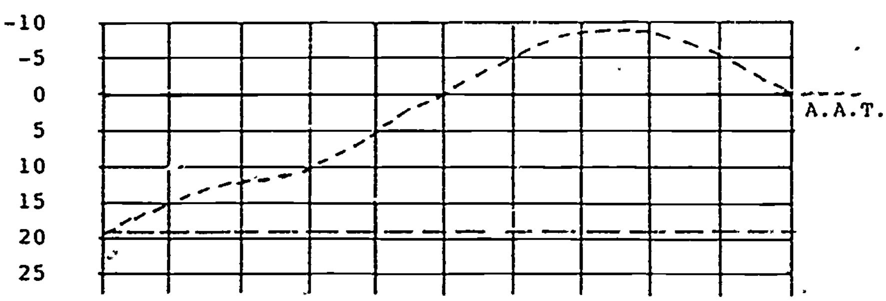


Fig. 4
MONAURAL THRESHOLDS. Dyslexic girl:

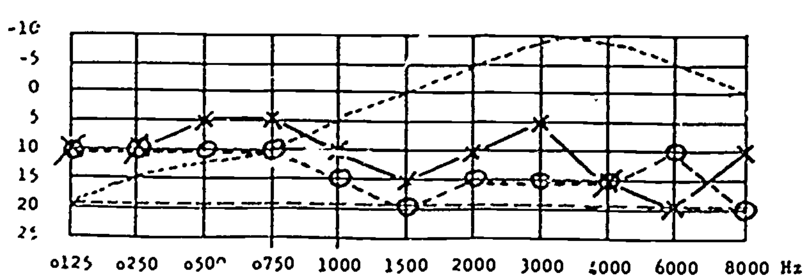


Fig. 5

Group 1: BPTA + / DL +
- 2: BPTA - / DL +
- 3: BPTA - / DL -
- 4: BPTA + / DL -

	Gr. 1 +/+	Gr. 2 -/+	Gr. 3 -/-	Gr. 4 +/-
Number and % total	5/ 10%	12/ 24%	16/ 32%	17/ 34%
Number and % females	3/ 16%	4/ 21%	3/ 16%	9/ 47%
Number and % males	2/ 6%	8/ 26%	13/ 42%	8/ 26%

Fig. 6

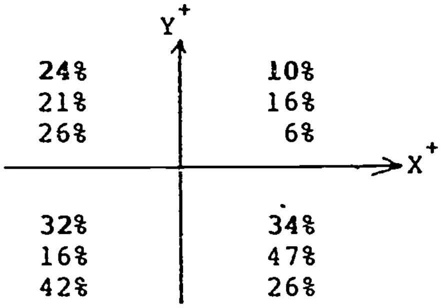
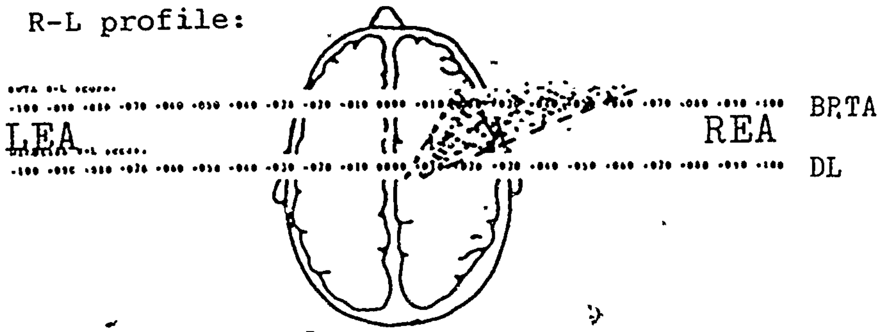
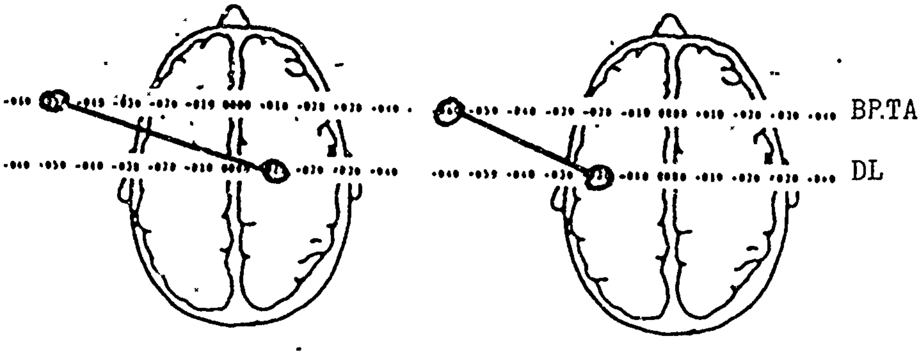


Fig. 7

R-L profile:



NORMAL ENVELOPE



TWO TESTPERSONS (RD's).