CROSSED LATERALITY

A STUDY IN ITS SIGNIFICANCE AND TREATMENT IN ORDINARY SCHOOL LIFE

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All paired muscle systems are represented in the brain by paired controlling centres. Dominance, or leading control of the function, may be entirely left-sided, in which case the organs controlled are dominant on the right side, or entirely right-sided. If some centres are on the left and some on the right side of the brain, the condition is called crossed laterality.

The dominance may be fixed, and diagnostic methods give no variation in results. In some children there is less fixity, one or the opposite centre taking control according to whim or circumstance.

These investigations were provoked by the observation of educational problems arising in a school of 150 to 200 children of both sexes between the ages of 6 and 16. The observations and investigations were carried on over a period of four years. The examiner knew all the children intimately, and lived among them continually. Thorough physical examinations were made at intervals of approximately nine months. Intelligence was measured and re-measured, using Terman and Merrill's tests, and Raven's progressive matrices. The teaching staff of the school used to meet regularly and frequently for discussion of the progress, educational problems and conduct of each child. In the capacity of School Medical Officer I attended all such meetings. There were unrestricted opportunities for investigation of these problems.

During the work report meetings it was noticed that some 40% of the children, at one time or another, presented some difficulty or failure in educational attainment. A further search revealed that 70% of these children had some type of crossed laterality. Viewed from another aspect it was known that 47% of the children in the school had crossed laterality, and of these 85% were in the group who experienced difficulties in school work.

The work here recorded was planned to discover: (1) Symptoms arising because of crossed laterality; (2) the effect of these symptoms on education; (3) the mechanism whereby these symptoms are produced; (4) why some cases of crossed laterality were asymptomatic; and (5) effective means whereby the handicap of crossed laterality might be overcome.

The Symptoms

Reversal of units in a series was the most prominent and basic phenomenon observed. This was found in any of the 'three R's' at any age. The child was never conscious of the error until it had been made. The symptoms to be described are not observed on every possible occasion. In different children they are present with varying frequency and persistence, depending upon the nature and the fixity of the irregularity, and upon what compensations the child has developed. Other factors which influence the appearance of symptoms are emotional tension at the time of examination; the type of teaching which the child has experienced, and the associated mental stress; the intelligence; and the speed with which puberty is being attained. No child will show all the symptoms observed, but each type of 'crossing' is associated with certain sets of symptoms. These symptoms do not occur in children without irregular dominance. Any child may make a mistake, and in the course of ordinary probability any particular mistake may be made. Those children who have these forms of irregular dominance show these symptoms frequently and persistently. Further, they find difficulty in learning to correct the mistakes, for the error occurs unconsciously.

It is not at all uncommon for children who are just learning to write to reverse letters, as b for d, or vice versa. Normal children learn the correct form quickly and without difficulty. Children with

irregular dominance are slow to make the correction, not readily appreciating the error. They have a marked tendency to repeat the error unconsciously. In older children the error may appear so that they seem to make careless mistakes in compositions and arithmetic. One can look upon a letter or figure as a diagram. More complicated diagrams have been prepared, and reversal of units of these may frequently be found when these are reproduced by children with irregular dominance. For example, this diagram (from Terman and Merrill's tests Form L 9 years) copied from visual memory may be reproduced with the corner units reversed thus:

When reading, reversal of the letters of a word may make something unpronounceable and meaningless, or occasionally a word that does not fit the sense. In the former instance, reading will be slow, and the child appears to stumble at small words. In the latter case the wrong word is read, delaying the perception of content, or if read aloud, the child is embarrassed and appears to others to be stupid. As an example, the child reading 'He saw a plum' may perceive and read 'He was a plum'. A similar fault is found in arithmetic, for the child reads or copies the figures of a problem in reverse, as 54 for 45 or 729 for 792.

Perception by hearing leads to reversal symptoms less frequently than if perception is by vision, for the opportunity is less. I have known it to occur when a child looks for a hymn that has been announced during a service of worship if he cannot see the hymn board.

It is characteristic of children learning to write, who have crossed dominance of eye and hand, that if the accepted normal standards of writing—position of person or paper and pencil—are rigidly enforced, the resulting script is poor. If the children are left alone to write as they please the script may still be poor, but they will twist the paper or the head. The children do not know why they do this, but all affirm that it is easier for them to write in this 'awkward way', and a diagnosis of 'poor muscular control' is frequent.

Children who use a left foot dominantly show no closely related symptom, but may provoke a laugh from their fellows who consider the foot work strange and awkward. But if the ability to kick well with a left foot wins for such a child acceptance as having a special ability, he will avoid the emotional

upset commonly seen to follow the symptoms of irregular dominance.

Children having complete left dominance show some of these symptoms, but with characteristic differences. Reversal mistakes in reading occur, but not in listening. Some prefer to write along lines that are oblique to the body. The use of the writing left hand above the line of script is only a means by which what has been written may be seen, the hand not then obstructing the view. Not all children using the left hand are completely left-handed; some have crossed laterality, and show the symptoms noted above.

Attempts to force the child to use dominantly a function which is not naturally dominant will cause symptoms to arise from the induced crossing, and also certain other evidences of cerebral turmoil. Symptoms arising thus are minimal when the crossing is not fixed, and when intelligence is high. The most widely known symptom resulting from attempts to change dominance is deranged speech. This can vary from complete aphasia to varying degrees of stammering. Other signs of nervous upset are also seen—not in themselves pathognomonic—such as enuresis and encopresis.

The emotional upsets that develop because of these symptoms are not isolated events but grow as the errors recur. The form which they take will depend upon factors such as age, development, speed of growth and intelligence. The following story is typical: The little child learning to write has a very poor hand, and the teacher finds that efforts to bring improvement meet with little success. Mistakes in reading recur so persistently that the teacher naturally begins to suspect that the child's mental capacity is not equal to the appointed tasks. Should he read silently, the content is gained too slowly; should he read aloud, errors are made over small words, and he becomes a source of merriment to his fellows. In arithmetic the persistent mistakes are labelled 'careless'. In consequence we find the child is frequently embarrassed in his class, and begins to echo his teacher's suspicion that he is mentally slow. He says, 'The harder I work, the worse I do.' It is easy, even reasonable, to cease to try hard and to drop into lazy habits. These children are difficult and often exasperating. No child of high intelligence fails without suffering, for he is conscious of ability and rebels against the suggestion that he is 'dumb'. He either becomes lazy and difficult or embarrassingly nervous, failing to keep pace with others, in spite of what appears to be tremendous effort.

How deeply this emotional trauma affects the child depends upon inherited physical factors and

upon intellectual capacity as well as upon the environment. The emotional conditions observed can be classified under certain factors thus:—

High Intelligence and Quick Development. If the irregularity is not fixed there is little of note except that the child learns more slowly than a similar child without the handicap.

If the irregularity is fixed, natural compensations develop with speed depending on the type of crossing and the intelligence. These children respond to sympathetic, helpful handling and symptoms are overcome. In cases where there has been other educational lack, or where there has not been good teaching, some symptoms will persist. The lack of progress will be covered by indifference leading sometimes to actual laziness.

High Intelligence and Slower Development. Whatever the fixity of the irregularity, these children are diffident. Natural compensations occur more slowly, and the child is constantly finding frustration. These children do not make progress as quickly as one might expect from knowledge of the I.Q.

Average (and Lower) Intelligence, with Quick Development. Symptoms are definite. Compensations are only slowly attained. Persistent mistakes stimulate a rebellious attitude towards the teacher, and methods of escape are planned and effected.

Average (and Lower) Intelligence with Slow Development. Symptoms are definite. Compensations are slowly attained. These children tend to be vindictive. The frequent mistakes and slowness to learn will be blamed upon their teachers.

Emotional disturbance is probably of greater importance ultimately than educational backwardness. When a child has failed to attain an adequate standard of reading and writing he will find his way into some gainful occupation which is not dependant upon these abilities. If he has grown up with feelings of frustration, inferiority and diffidence, these will prove ever present trials in any walk of life.

Diagnosis of Ear, Eye, Hand and Foot Dominance

It is reasonable to speak of dominance of one of a pair of these functions only if each of the organs concerned is practically normal. The ordinary variations between the eyes, due to differences of refraction, do not determine dominance. The following methods have been found to give consistent results. When seeking to determine dominance it is essential that the child be absolutely at ease, happy and generally interested and yet ignorant of the

object of the test. It is a good plan, therefore, to space out the tests at different times in the course of a physical examination, and also to use a variety of tests.

Ear. During examination of the ears for hearing acuity the child is made to stand in front of the table upon which rests a watch on a cushion. He is asked if he can hear it. The watch is then covered by a cloth, or placed in a box, and the question repeated. If the child is not able to hear the watch, he is told to get closer to it, and still closer until he can. It will be observed that as the child bends or approaches the watch, he will bring either the right or the left ear nearest. This is the dominant ear. This test must be varied in form from time to time and from child to child.

Eye. Many tests have been described for the determination of eye dominance. Some have proved unreliable in small children because of difficulty in gaining their cooperation. The following tests and simple variations have been found reliable. A small bright object on the far side of the room is observed by the child through a small circular hole about $\frac{1}{2}$ in. in diameter in a card held at arm's length. The examiner stands behind the child and observes the line object-hole-eye. This eye will probably be the dominant eye. While still in that position, the other eye is shaded and the child asked if he can still see the object. If the original line has been noted correctly by the examiner he will answer in the affirmative. The presumed dominant eye is now shaded. The child will say that he does not see the object, and will move the card until the other eye takes up the line. There is more difficulty in lining up the non-dominant eye. The card will be moved up and down and round about until it is in position, an action quite distinct from the quick way in which the dominant eye is lined up. This test is very reliable, but too difficult for small children.

The following test I have found acceptable to a small child; it gives satisfactorily consistent results and can be modified almost indefinitely according to circumstances. On the hillside opposite to my consulting room there was a wooden shack which had three windows of different sizes. The child was given a cardboard tube, told to pretend that it was a telescope and to look at the 'large-sized window, the middle-sized window and the smallest window' to see if any of the bears could be seen. The child uses the dominant eye. A kaleidoscope, a toy telescope and such playthings can be used effectively.

During a test for visual acuity the child is given a small refraction mirror with a central hole. He is told to use this looking from the black side through

the small hole at the lower letters on the eye chart to see if they appear blacker. He will use the dominant eye, and in most cases make no movement to use the other, indicating that his thoughts are on the letters rather than the eye. The result is therefore the more likely to be reliable.

Hand. If a small child is given a pile of blocks and is told to build a tower, the highest blocks, whether the pile is of single or of many columns, will be placed with the dominant hand, for that can be used more delicately and with better control. Older children, able to write, will use either a dominant right hand naturally, or a right hand which has been 'changed', or a dominant left hand. The child then takes the pencil in the other hand and endeavours to write. The dominant right-handed child holds the pencil awkwardly and does very poor script or none at all. The 'changed' child takes the pencil with the left hand, holds it easily and makes a presentable script. The true left-handed child finds the use of the right hand as difficult as his right-handed fellow does the left hand. The dominance of eye and hand together may be shown if a child is asked to thread a needle. He will observe the eye of the needle with the dominant eye, and may even close the other eye. He will hold the thread in the dominant hand, for this hand will have to make fine movements, and the needle in the non-dominant hand, for no movement is required at all.

Leg. When the little child has built his tower of blocks he is given a small wooden ball, which is placed on the floor 6 or 10 feet away. He is told to kick the ball so that it knocks the tower down. It is probable that he will have to make more than one attempt. Accurate aim when kicking is obtained only by using the dominant leg. In older children this may have become apparent already for the child is known to be a useful left wing in football. Older children have been tested in the following manner. Standing on the far side of the room from the examiner, they are told to kick back to him a ball he rolls to them. A child with a dominant right foot will do this with the right foot. The ball is rolled again, but this time to the right of the child. He will still return it with the right foot. The ball is then rolled again to the left of the child, and the child will turn so that he will kick the ball back again with the right foot. A child whose left leg is dominant does just the reverse at these different stages.

Balance has been used to determine leg dominance, for the dominant leg or foot is used to restore position to the body when the balance has been upset. This is best observed in the child's play. Any

test designed to upset the child's balance may frighten him if unexpected and so spoil 'rapport' between examiner and child. But if the child be warned, he will not act naturally or unconsciously, and the value of the observation becomes questionable.

As has been noted, observation in work and play can be of great value, and is almost the only reliable way of tackling the problem in very young children. Some acts, such as the 'high jump' and digging, use a number of organs, and can be used in confirmation of the results obtained by the specific tests.

Equivocal results indicate that dominance in one of a pair is not fixed. If modifications of the test are made on different occasions it will be seen whether there is real lack of dominance, or whether the equivocal result is due to lack of understanding on the part of the child. The lack of complete dominance is revealed by the use of one of the organs concerned, but a readiness to use the other if that be more convenient. For example, one ear will be used, but if the child cannot hear, he may turn and use the other; one eye will be used, and then the other; one foot may be used to kick the ball back to the examiner, but when the ball rolls nearer the other foot, this will be used as easily as the first. Such results are of importance, for they have a bearing upon prognosis of treatment.

Notation

The following notation has been found convenient. The capital letter R and L indicate dominant function, as right or left (not cerebral centre). When either of the paired organs may be used satisfactorily, neither being dominant but used according to the subject's convenience, small letters are used, r and l. But in these instances they will of necessity be in pairs, rl or lr. When the dominance is definitely on one side, but there is ability on the other, it is indicated thus, Rl or Lr. The organs described are recorded in the order, ear, eye, hand and foot. If, for some reason, the dominance of one of a certain pair cannot be determined, as for example if the subject has a blind eye, the space in the series is noted by a full-stop. When the position of the centre is not known its place is indicated by O. If the type of dominance is irrelevant to the argument, this function is indicated by the oblique line /. The position of the speech centre is indicated by the use of R or L in brackets (R) or (L). This naturally refers not to the observed function but to the actual cerebral centre.

For example, R R R R indicates that the subject's ear, eye, hand and foot, are dominant on the right

side, the cerebral centre being on the left. L L R R indicates that the subject's ear and eye are dominant on the left side, but that the hand and foot are dominant on the right. R L R L indicates that though the right ear, left eye and left foot are dominant, the right hand shows more skill than the left, but the left also has ability. L R (L) R L indicates that dominant function of ear and foot are on the left, and of eye and hand on the right. The speech centre is deduced by experiment to be on the left side of the brain.

Aetiology

A clue has been found to the development of crossed laterality from a study of family histories. The children in this series belonged to 70 families. All the cases of irregular dominance were found in 57 of these families. Fresh cases of crossed laterality were found among other brothers and sisters of these families, not pupils of the school. Those children who showed equivocal findings all had sibs with definite irregular crossing, and therefore showed the condition in the family tree. Similarly, an isolated left ear dominance was found only in those families where there were other types of crossed dominance.

Complete and accurate family histories are rarely obtainable, for diagnosis in an adult may be difficult or, if absent, impossible. Occasionally one can learn of relatives who were definitely left handed, or were known to have left dominance of eye or foot. Again, one hears of relatives in these families who were known to have shown symptoms, particularly bad writing, bad spelling, stuttering, or of having been changed from right to left handedness.

The condition may arise spontaneously in one of uni-ovular twins, one having complete right and the other completely left dominance. Most commonly it is found that one or other or both

of the parents have irregular or left dominance. Among the offspring complete left and complete right dominance or any type of crossing occurs. Occasionally I have found two or three children in a family with definite irregularities but with no relative known to have anything but the usual right dominance. I have also noted apparently normal parents who have brothers or sisters affected. These latter two observations raise the possibility of the transference of a recessive factor, but such instances are the exception. An obvious family history is the rule.

The following family trees are typical of those collected. Incompleteness is largely due to the relatives being scattered over four continents, and therefore beyond examination, and sometimes unknown to the parent questioned. These symbols have been used:

Condition not known:	Male	□	Female	○
Definitely unaffected		◻		◯
Definitely affected		■		●
Died young		◻		◯

The letters by the symbols refer to description in the legends of the individuals marked.

All subjects known to show any left-sided dominance, complete or incomplete, are regarded as 'affected' in these pedigrees, and in this section of the discussion.

These five histories illustrate the conclusions regarding inheritance which have been confirmed by similar histories of other families. Persons examined are indicated.

Families 1 and 2. Show inheritance through three generations.

Family 3. Shows persistence of genetic factor, in spite of an apparently successful change of mother from right to

Family 1

- A. Known to use left hand and foot, but having right hand ability.
 - B. Known to use right hand and foot.
 - C. As A.
 - D. L L l r L. University graduate.
 - E. R R R R. Knows of no symptoms in family.
 - F. r l R R R. No symptoms.
 - G. R R R R. No symptoms: clever.
 - H. l r L R R age 6: early schooling very handicapped by symptoms.
 - J. L L L L age 4. Has had no schooling.
- D, E, F, G, H and J are the only individuals known and examined.

Family 2

- A. Left handed.
 B. Thought to be right handed.
 C. D. E. Completely right, without symptoms.
 F. L L L L.
 G. Attempt was made to change dominance—failed entirely.
 H. Completely right, no symptoms.
 J. Lr R R R. Average ability, very little trouble except enuresis.
 K. rl R R rl. Average ability: no symptoms.

L. L L R R. Stuttered as a child, fair ability, handicapped by bad spelling.

M. R R R R. Poor ability but no symptoms.

N.O.P. No known symptoms, thought to be right handed. Not examined.

C, D, E, F, H, J, K, L, M are the only persons known and examined.

Family 3

- A. Changed from left to right hand for writing.
 B. Left handed.
 C. Right handed, no known symptoms. Very clever.
 D. Left handed aged 3.
 E. L R L R. Intelligent, but very poor writing.
 F. Left handed. Family not known.
 G. School work slow and poor. Blinks continually. Right handed.
 H. Suffers with a nervous tic.
 E is the only individual known and examined.

Family 4

- A. Left handed.
 B. R R R R.
 C. R R R R. High intelligence.
 D. L R R R.
 E. R L R R. Poor average I.Q. not yet at school.
 F. R R R R.
 A, C, D, E, F all known and examined. History obtained through F who was not very familiar with her husband's family.

Family history obtained from K, L, M and N, who were all unaffected.

F.G.H. known and examined, J. abroad, age 4.

A. A left-handed bowler.

B. Left handed.

C. Able to read well, but would never read aloud.

D. Left hand, changed to right and became bad in reading and writing. Stuttered.

E. Backward in spelling and reading with symptoms of emotional upset through schooling.

F. L L Lr Lr. Average intelligence, backward at school because of very troublesome reversals.

G. R R R R. No symptoms.

H. L R R R. No symptoms under ordinary conditions.

J. Known to be left handed. Not examined because of being abroad.

left handedness. Also illustrated the possibility of a child inheriting the condition through a parent not known to have symptoms, and possibly without the condition.

Family 4. Shows inheritance through an apparently normal father, in whose family there is left handedness.

Family 5. Left handedness is recorded in the families of both parents (in the case of one, with very severe symptoms), though each parent is apparently normal. The mother, N., had lost the sight of the right eye through an accident when aged 18 months.

Natural Compensations for the Symptoms

How frequently the symptoms of crossed laterality occur depends on the extent to which compensatory methods are developed. The presence and significance of these are unknown to the child in the majority of cases. They arise unconsciously, and are most developed in children with high intelligence and of fixed irregularity. Correct perception is obtained by multiplying the stimuli received. The lesser the child's intelligence, the slower he will be able to compensate in this way.

When the ear is used a smooth, soft monotone is a single stimulus. If rhythm or emphasis be added to the sound, the memory of music is also stimulated. The louder the sound heard, the more likely it is that both ears will be used, and not the dominant ear alone.

The child looking steadfastly at a design he has to reproduce from memory will sometimes be observed

to move a finger as though following the pattern as he will draw it. This addition of kinaesthetic memory ensures correct perception. Ocular perception is sometimes corrected at a later stage. When the child perceives that what he has read does not make sense he will re-read correctly. This depends entirely on his mental ability. Slower children go to the stage of transferring the perception to speech. Then, having heard what they have said, the need to correct is known and effected. Just as loud sounds make incorrect perception unlikely, so large visual images are more accurately remembered.

A still different approach has been seen among those children whose irregular dominance leads to incoordination of hand and eye. When writing they turn the paper so that the line of writing is at an angle to the body. They find this easier and their efforts more acceptable.

The Course of Crossed Laterality Uninfluenced by Treatment

Crossed laterality has been brought to notice in recent years, not only by careful observation, but because a greater opportunity for the development of symptoms as formal education has become more general. Persons engaged in outdoor or manual occupation are not subjected to the same mental activities as those engaged in more intellectual tasks, and do not show these symptoms. If the early

schooling has been adequate the intelligent child unconsciously gains compensation for his handicap, and is almost without symptoms.

I have found no evidence that real change of cerebral dominance ever occurs. If the dominant one of a pair of cerebral centres is destroyed before the age of 5 or 6, the other will gradually gain complete control of the function. At a later age full function is never attained. When one of the organs becomes useless a similar course will be followed. In neither of these instances is the basic inherited pattern altered, nor are the genetic potentialities of the individual changed.

Varieties of Crossed Dominance Found in this Series

Groups I and II. L R R R, 16.0%; R L L L 0.6%. These are almost without symptom or handicap in ordinary school life. Under artificial condition reversal can be demonstrated from reception by hearing to expression by speech or writing.

Groups III and IV. L L R R, 10.6%; R R L L 0.6%. The most serious symptoms occur in these groups.

Groups V and VI. L R L R, 1.2%; R L R L, none found. Reversal symptoms occur in speech and writing, but corrective mechanisms readily develop.

Groups VII and VIII. L L R L, 1.2%; R R L R, none found. Reversal symptoms occur in speech and writing, but corrective mechanisms readily develop.

Groups IX and X. R L R R, 14.6%; L R L L, 0.6%. Serious symptoms occur as in groups III and IV.

Groups XI and XII. R L L R, none found; L R R L, 0.6%. Symptoms as in groups I and II.

A potential handicap was present therefore in nearly 28% of children in this series.

Complete left dominance was present in 4% and complete right dominance in 49.3% of the children seen. The sex distribution was equally divided, both among the children with crossed lateral anatomy and the remaining children. There was a very slight, probably insignificant preponderance of males among those showing symptoms that could be related to this condition.

When the intelligence quotient is 120 or higher evidence of crossed dominance is readily masked by the child's unconscious development of compensatory mechanisms.

Experimental Investigation

Although unconscious reversals occur spon-

taneously in ordinary school life, they can also be provoked artificially. This was observed while making intelligence tests with the material prepared by Terman and Merrill. In the course of repetition of a series of figures it was found that a child with irregular dominance might reproduce all the digits but reverse the position of two. This error was not perceived by the child, who appeared satisfied that he had done what had been required. Because of errors of this kind a serious number of months of mental age might be lost, vitiating the quotient. By accepting the series as correct, even though two units were reversed, a quotient more in keeping with the findings of other non-verbal tests was reached.

Many series of figures and letters were prepared for presentation to the child in these experiments. Care was taken that each should be a single stimulus. Thus, letters like b and d were not placed together in a series, nor as terminal letters in consecutive groups; letters in alphabetical sequence, and those occurring together in spelling frequently, as g and h, or t and h, were omitted. Letters were not grouped so that any word or well known acronym could be assimilated, as W H Y C, or U N O X, or S T M W; all vowels were omitted because words or syllables might be formed. Letters which might be confused with other letters through similarity of sound were not used, as j and k. The figure series were constructed so that there should be no sequence or progression which might have been appreciated by a bright child, as 2 8 3 4 7, or 1 2 4 8, or 2 3 7 8, or 4 1 8 5, and so on. Throughout the experiments no child was given the same series twice. Fourteen distinct series of letters and figures were prepared for each child, and if repetition were subsequently required another series would be constructed.

The ability to reproduce a series depends upon the mental age of the child. Three groups of three were first presented; then three groups of five; three groups of six; three groups of seven; and three groups of nine. With figures it is known that a mental age of 3 repeats three figures, of 4½ four figures, of 7 five figures, of 10 six figures; series of eight and nine figures are repeated by those having a high adult standard of intelligence.

Letter series of similar length could be repeated at about the same intelligence level. Reversal of units occurred unconsciously with those having irregular dominance, even from the shorter series, but as soon as a series above the mental age level was reached, this type of error was replaced by complete confusion of the units repeated, in kind, number and order. The child became conscious of error, and no useful purpose was served by proceeding with the tests at these higher levels, for it

caused the child to become embarrassed and spoiled *rapport*.

The method of presentation was carefully planned so that the child met a single stimulus. At a later stage in the tests two single stimuli were simultaneously applied. When hearing was to be used, the series was spoken to the child by the examiner in a soft regular monotone, at a rate approximating to two units a second. A simple apparatus was constructed so that the child might view the series for a similar length of time, after which it became hidden. The letters were in block capitals, and both letters and figures of a size corresponding to 6/6 vision at 3 feet. Similar series were prepared so that they might be presented to the child vertically.

Expression was made to be a single effort. When writing the child was told to write immediately and not to repeat to himself, either before or while writing, the series. This was not always easy for some children because of habits they had formed. It was observation of this difficulty and its effects which suggested the combination of expression; thus, the child would write what he had seen or heard, and then repeat it by speech without reading what had been written. And, alternatively, he would repeat what he had perceived, and then write it.

These tests are time consuming, and the child easily becomes fatigued. It was found best to keep even the most intelligent no longer than 20 minutes at any one time and to complete the tests on subsequent days.

The findings are summarized in the table on page 256.

If the child's eyes are watched as he reads—a mirror is placed in the plane of the book and the observer stands behind the child—they will be seen to move in tiny jerks from side to side. If the right eye is dominant the eyes jerk towards the right; if the left is dominant, although the eyes are still moved towards the right, sudden movements in the opposite direction occur simultaneously with reversal of what is seen, or a stumbling in the reading. When presented with a picture of a number of objects, none being a principal feature, the child who is right eyed will enumerate the objects from left to right, and the left-eyed child will do the reverse. The movement of the eyes may be known subjectively when travelling at speed in a train. The right-eyed traveller, facing the way he is going, reads notices or station names more easily if he looks over his right shoulder than similar notices seen as he looks over the left. When he sits with his back to the engine the opposite is true. But, if the traveller is left-eyed, all these observations are reversed. In the forementioned experiments it was found that,

while horizontal presentation of a series to the eye resulted in reversals appearing, vertical presentation did not do so. Children with the cerebral pattern / L L /, and / L R / find that they can write better and more comfortably with the book on a slant. The hand moves of necessity from left to right, but the eyes do not follow this direction naturally. By using an oblique path the eye can maintain control over the hand more easily. When a child writes a line six inches long, parallel to the line of his shoulders and eighteen inches distant, the eyes must sweep through a horizontal angle of 20° . If the book is turned through an angle of 60° the horizontal sweep of the eyes is through 8° , and the vertical sweep through 16° . If now the plane of the book is depressed from the child through 45° the vertical sweep required of the eyes is now $10\frac{1}{2}^\circ$.

The Mechanism of Reversal Symptoms as Deduced from Experimental Findings and Observed Natural Compensations

Dominance of a cerebral centre ensures that the function of the corresponding muscle is delicate and accurate. In the ear the tensor tympani controls the sensitivity of the drum to the pitch of the sound sought. Each ear may be completely sensitive throughout the whole range of audible sounds, but the child prefers to use one ear when listening intently and so, presumably, the impression is more fixed on that side of the brain. Observations of eye movements show the method by which reversal occurs. Accuracy of vision is determined by use of the ciliary muscles, and so there is preferential use of a single eye when observation is made through a small aperture. Because of the optic decussation, visual perception is equal on each side of the brain. Similar delicacy of control is attained in both hand and leg or foot movements through a dominating cerebral centre. This is noticeable when a child builds a high tower of blocks, and when he attempts to use the non-dominant hand for writing.

The reversal symptom arises when what has been perceived is expressed through the medium of a dominant cerebral centre which is on the opposite side of the brain from the dominant centre of perception, as is shown in Experiment 1. Visual perception is not reversed in this way, for both sides of the brain have been equally stimulated. When the eyes are required to observe and reproduce a series in a direction opposite to the natural movement, irregular movement of the eyes will result in inaccurate perception, and consequently in inaccurate expression. This is demonstrated in Experiments 3 and 4.

Speech is controlled from two cerebral centres.

Experiment No.	Method of Reception	Method of Expression	Dominance Patterns showing Reversal Symptoms	Types of Crossing according to Groups (page 254)
1	Hearing	Writing	Right ear and left hand dominance and vice versa	I, II, III, IV, VII, XII
2	Hearing	Speech	Found sometimes when ear and hand dominance were opposite, and also when ear and eye dominance were crossed, even though ear and hand dominance were in agreement. This suggests that in such cases the speech centre is situated in the cerebral hemisphere corresponding to eye dominance rather than in that related to the dominant hand	I, II, III, IV, V, IX, X, XII
3	Sight	Writing	With left eye dominance irrespective of hand dominance	II, III, VII, IX
4	Sight (horiz.)	Speech	With left eye dominance irrespective of hand dominance	II, III, VII, IX
5	Sight (vert.)	Writing	None	
6	Sight (vert.)	Speech	None	
7	Hearing and sight (horiz.)	Writing	None	
8	Hearing and sight (horiz.)	Speech	None	
9	Hearing	Writing then by speech	Reversals occur at the first as in Experiments 1, 2, 3, and 4 If reversals occur at the first stage they are repeated	
10	Hearing	Speech then by writing		
11	Sight	Writing then by speech		
12	Sight	Speech then by writing		
13	Hearing and sight (vert.)	Writing	None	
14	Hearing and sight (vert.)	Speech	None	

This is to be expected since the muscles used are in pairs. Confirmation of this is found in pathological processes. If a cerebral abscess occurs in the region of a speech centre, speech will be completely lost when the presumed dominant centre has been destroyed. But in early childhood speech will be gradually regained as the opposite side takes over control. But after the age at which cerebral anatomy has reached full development, perfect speech will not return. An opposite train of events is seen if the non-dominant centre is destroyed by the abscess.

Since reversal symptoms occur between ear and hand when the dominant centres are on opposite sides of the brain, it may be reasonably presumed that reversal following the transference from ear to speech indicates that the speech centre is on the side of the brain opposite from the dominant auditory centre.

In Experiments 5 and 6 it will be seen that with the vertical presentation no reversals occur. So, when the child reads or writes along a line more vertical than horizontal the dominant left eye is afforded less opportunity to act irregularly.

By combining the two main stimuli of hearing and sight, as in Experiments 7 and 8, reversals are again avoided, even though each stimulus of itself might lead to the symptom. The sound checks the movement of the eye, and prevents inaccurate perception. Then, accurate perception having been obtained at

the visual level, this corrects any tendency to reverse from ear to hand or speech. In Experiments 13 and 14, the vision, being accurate, corrects the tendency of reversal from ear to expression.

Experiments 9, 10, 11 and 12 were planned to show the value of two forms of expression. It was found that any error made at the first stage of expression was repeated at the second, but that errors did not arise *de novo* in the second stage. The initial stimuli were, of course, single. When a child is reading his perception of the sense of a passage may correct what he has seen, or when he hears that he has said something absurd, he will look again and correct himself. This, of course, cannot occur when pure stimuli of sound or sight are used, though it is not uncommon in ordinary life.

Reversal symptoms may be avoided if the initial stimuli are multiple. For example, ear to writing does not reverse if emphasis and rhythm are added to the sound. The louder the sound, the less likely that only the dominant ear will be used. Similarly, vision will be accurate if the figures or letters are very large. It is often seen that some children add kinaesthetic memory to vision so that they can reproduce a design correctly. Irregular eye movements are avoided when the left-eyed child is prevented from using the eye in a left-right horizontal direction.

Treatment of Crossed Laterality

Transference of dominance from its natural side to the cerebral centre on the opposite side can only occur if the first centre is completely destroyed while the child is still very young. Similarly, but with more hesitation, the same may occur if the organ concerned becomes functionless. After the child has reached the pre-puberty age of 6 to 9 years full function is never regained. Such catastrophes cannot, of course, be reproduced as a form of therapy. Attempts to change the dominance by forcibly restricting the use of the dominant functioning organ—this is usually the hand—meet with varying degrees of apparent success. Forcible restriction of the use of the dominant hand does not stop the cerebral function, though the nervous impulses cannot find expression. As a result the function is initiated, first from one centre and subsequently from the other. This state of cerebral turmoil or indecision is shown in clumsy hand movements. The turmoil spreads and other centres are involved. For example, speech ceases to be the expression of one centre. The resultant stammer is comparable to putting two men on the driving seat of a coach and pair.

The degree of success depends upon the fixity of the original cerebral pattern and upon the intelligence of the child. If the intelligence is high, it may appear that there has been complete success, but these children always show some irregular dominance. Treatment must be aimed at overcoming the symptoms which handicap the child. A clue to this has been given by observing the compensations developed by intelligent children. The methods used have been amplified from experimental findings, and have proved successful in dealing with these handicapped children.

To prevent incorrect expression of what is heard it is necessary to avoid the single use of the dominant ear. In place of a soft monotone (as of a tired teacher) a full sound, with rhythm and emphasis must be made. This is easy with reading or the lecture type of lesson, but there are sometimes difficulties when figures are read either by the child or the teacher. This difficulty has been satisfactorily met by adding a musical memory. Each figure has its own musical pitch thus:

The number 9461 would then be read as:

This does not involve any musical ability, and can be used by a child even when reading silently. Reversal is absolutely avoided.

The problem of accurate expression of what is seen is approached differently. Where hand and eye have opposite dominance, writing can be made easier and more regularly formed if the child is taught to turn the book and write obliquely. The child with /LR/ should write away from himself, and with /RL/ towards himself. Reading for these children can also be made easier if the book is held obliquely. Reading for content must not be hurried until the child has overcome the handicap entirely. These children should not be expected to read alone problems written on a blackboard, especially if numbers are involved. While the child looks at the board, the teacher should read the problem using correct emphasis, and the musical notation for numbers. After a period, the length of which will vary with the type of cerebral irregularity and the child's intelligence, it will be reasonable for the child to work alone.

When incorrect perceptions have already become common the child will have difficulty in spelling, a difficulty which increases rather than being overcome. The essential need is to obtain a correct appreciation of the form of the word. This may be done by considering the word as a design which is to be reproduced and adding kinaesthetic to visual memory. The word should be written by the teacher on a strip of paper in large (1 to 2 inches) copper-plate letters. The child then traces over these letters, using the whole arm, and keeping the finger tip on the writing he is following, while the word is pronounced in letters or syllables. This is done several times until the child is sure of the word. There is nothing to be gained by hurrying, and making a mistake is a backward step. Unless the child is certain he should return again to the copy. This usually results in a noteworthy improvement quite quickly, but it must be remembered that there is probably a debit balance of bad spelling to be erased from the memory. New words will be learned more quickly than old words which have been fumbled or always spelt with one persistent error. This method of learning new words must be used almost indefinitely. If it is neglected the child drops back into all the old troubles in the course of a few months. The advice that children should write the

word in the air or on the desk before they do so on paper does not meet this difficulty. When the child does this he is expressing what he has perceived, not correcting his perception by the addition of kinaesthetic sense.

When it can be shown that the child has ability to use both hands he should be trained to use first of all the hand that brings dominance completely to one or other side. Thus, L L rl L should be taught to be L L L L and R R rl R should become R R R R. Having set the child to develop in this way, the ability of the other hand should not be suppressed, but encouraged to become a useful ancillary hand. Sometimes a child shows some degree of ambidexterity, but is so crossed that he cannot be trained into either complete left or complete right dominance. He should then be so taught that the hand of which is required the highest skill fits best into the pattern of cerebral dominance and produces minimal symptoms. For example, L L rl R will probably turn out best if he be trained to become L L R R. Then expression and reception are balanced. But if the position of the dominant speech centre is determined one can train the child into a more secure position; thus L L (L) rl R will do better as L L (L) L R while L L (R) rl R should be taught to become L L (R) R R. A watch should be kept lest the child shows any symptoms of distress and adjustment made accordingly.

Emotional disturbances will have occurred if symptoms have persisted for any length of time. This will respond to general treatment if the underlying cause is corrected. When the condition is found in the early stages of schooling (this is the time when diagnosis should be made) the child must be taught the way to compensate for the handicap, but at the

same time the child, his teacher and his parents should understand that he is not abnormal in a pathological sense, but rather different from many, and with special abilities. When intelligent, older children are discovered who are failing at school or who have become lazy, a big advance will be made by explaining to them their handicap, and why they have failed. Demonstration to such a child of his real ability to reach the right answer, even where he has failed (as, for example, in spelling), when he uses the methods suggested is usually followed by a fresh, enthusiastic attack on his work, and he begins to take his proper place among other children.

Summary

Crossed laterality was found among children in a boarding school. Its prevalence and aetiology are examined.

The natural history and symptomatology are related to observed educational problems.

Experiments are described whose aim has been to discover the mechanism whereby the symptoms arise.

Effective treatment, which has been suggested by observation of the natural history of the condition and of experimental findings, is recorded.

I would acknowledge the kindness of the Lord God in giving this unique opportunity of studying His workmanship, and His guidance and help as problems have been spread before Him in prayer.

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