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SOME LONG-TERM MOTOR EFFECTS OF CEREBRAL COMMISSUROTOMY IN MAN*

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Abstract—The long-term effects of cerebral commissurotomy on motor co-ordination and dyspraxia were investigated in 8 patients who had undergone complete or partial commissurotomy 5–10 yr previously. Performance on a series of standardized motor co-ordination and manual dexterity tests was compared with the established norms. Although qualitative performance appeared essentially unimpaired on most tests the scores for speed were consistently below normal and also inferior to those reported for patients with various unilateral brain lesions. In certain bimanual tasks requiring rapid alternating motion and interdependent control severe qualitative and quantitative impairments were present. In addition, marked dysgraphia and mild ideomotor-type dyspraxia on the left side, and moderate dyscopia on the right were present up to 10 yr after surgery in patients with complete commissurotomy. It would appear from the results that interhemispheric communication becomes particularly important for motor output to the extent that the tasks involve complex intermanual co-ordination or hemispheric specialization with ipsilateral control.

FROM AN anatomical consideration, surgical section of the cerebral commissures appears to create a wide spectrum of problems for motor integration. In particular, severance of interconnections between the main sensorimotor cortical control systems for left and right limbs and the disengagement of the main language centres from all motor outflow of the right hemisphere might be expected to produce conspicuous motor symptoms. Nevertheless, commissurotomy patients have been found to retain excellent bimanual motor co-ordination in most daily activities that already were highly practiced prior to surgery. Bilateral integrations like those involved in tying shoelaces, buttoning clothes, lighting cigarettes, shuffling cards, cooking, swimming, bicycling, and the like continue to be performed after recovery from surgery with little if any significant impairment [1].

On the other hand, motor deficits after commissurotomy are pronounced under controlled testing conditions that require crossed motor response to lateralized sensory input or central processing as in motor replication of complex digital postures pictured in the opposite visual hemifield [2–4]. Even under conditions of free vision dysgraphia in the left hand and dyscopia in the right are present early in recovery and evident in some patients 2½ yr after operation [5]. A persistent marked impairment in ability to learn a new bimanual motor skill with free vision 9 yr after operation was recently demonstrated by PREILOWSKI [6, 7] for a complex visuomotor integration task that required continuous mutual monitoring between the hands.

A general assessment of the long-term effects of commissurotomy on motor co-ordination including the extent to which early motor deficits can be compensated with time and practice and new bimanual skills acquired by learning remained to be made. The present

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study was undertaken with this aim utilizing a series of conventional clinical tests for praxis along with a large number of established motor dexterity tests for which standard norms are available in the literature. Although some re-educative compensation was found to be present 5–9½ yr after commissurotomy, especially in the youngest patients, the scores for motor performance nevertheless remained generally substandard on most tests and definite disconnection symptoms were still in evidence.

SUBJECTS

The subjects were 8 commissurotomy patients of VOGEL and BOGEN of Los Angeles. All had undergone a single-stage surgical disconnection of the cerebral hemispheres for alleviation of intractable epilepsy. Age of testing and number of years since surgery are listed in Table 1 along with manual deficits known to be attributable in certain of the patients to other than commissural damage. Six of the patients had presumed complete section of the entire corpus callosum and the anterior and hippocampal commissures [8]. Two patients (DM and NF) had a partial commissurotomy in which approximately the anterior two thirds of the callosum and the anterior and hippocampal commissures were sectioned preserving the splenium [9]. Whenever the massa intermedia was visualized it was also divided as was the case in NG and NW. All patients before and after operation were predominantly right handed in writing, eating, and other common activities as verified by the Harris Test of Lateral Dominance [10]. (For further review of medical case histories see [5, 9, 11, 12].)

Table 1. Summary of commissurotomy patient's age, sex, years since surgery, and extra callosal damage resulting in manual deficits

Patient	Sex	Age when tested	Years since surgery	Manual deficits due to extra callosal damage
NG	F	40	9½	
LB	M	21	8	
RY	M	49	7	
NW	F	43	6½	
AA	M	22	8½	Right arm—birth injury
CC	M	21	8	Right arm—birth injury
NF	F	31	4½	Right arm—stroke
DM	M	28	5	

METHOD

A series of manual dexterity tests for which standardized norms were available for comparison was administered in free vision to each patient. Most of these tests had not been performed previously by the patients according to our records and patient recollection. Administration and scoring procedures followed instructions of the test manual where these were available or published reports where a comparison with other brain lesioned patients was involved. All tests involved the common instruction, "work as fast as you can", and scores were evaluated in terms of speed. Scores were based either on time taken to complete the task or on number of items completed within a prescribed time. Most tests involved highly prescribed and repetitive movements. Six permitted some measure of learning in terms of improvement with multiple trials. The levels of perception and memory required for performance were minimal so that failures were not attributable to these factors. Most tests were administered in the laboratory and/or patient's home usually for 1–1½ hr a session and not more than once a week for each patient. In addition, batteries of traditional clinical apraxia tests were given. Brief descriptions of the individual tests are listed below.

MacQuarrie Test for Mechanical Ability (*MacQTMA*)

Three subtests were administered:

(a) *Tracing*. Subjects draw a line with a pencil through a series of randomly positioned narrow spaces on a printed form. Score is number of openings passed in 50 sec without touching the sides.

(b) *Tapping*. Three dots are marked in each of a series of printed ⅜ in. circles. Score is number of circles completed in 30 sec.

(c) *Dotting*. A single dot is placed in each of series of $\frac{3}{16}$ in. circles arranged in an irregular pattern. Thirty seconds are allowed. Score is the number of dotted circles divided by three [13].

Minnesota Rate of Manipulation Tests (MRMT)

Consisting of 5 parts this is the most extensive test used. In general, it requires the subject to transfer 60 cylindrical blocks into holes in a different manner for each subtest as follows: The right hand is used in Placing, Displacing and One-hand Turning and Placing, and both hands are used simultaneously in Two-Hand Turning and Placing and alternately in Turning. Score in each case represents the summed time taken to complete the task in 4 consecutive trials [14].

Crawford Small Parts Dexterity Tests (CSPDT)

With the right hand a pair of tweezers is used to transfer small pins (1·75 cm long and 0·1 mm wide) from a bin into close-fitting holes and to put collars over each protruding pin (Part I, Pins and Collars). Using both hands 36 small (1·25 cm long and 5 mm wide) screws are lifted one by one and threaded into holes with a screwdriver (Part II, Screws). Score in each part is the time required to complete the task [15].

Stromberg Dexterity Test (SDT)

Tricoloured cylindrical blocks are placed in a prescribed order in correspondingly coloured sections of a 54 hole formboard. Only the right hand is used. The two scores are time required to complete two different versions of this task [16].

Pennsylvania BiManual Worksample (PB-MWS)

The first part (Assembly) involves twisting together 80 nuts and bolts ($\frac{1}{4}$—20 × 1) and placing them in order in holes. In the second part (Disassembly) 100 bolts and nuts are untwisted and placed in separate bins. Simultaneous use of both hands is required. Score is the time needed to complete each part [17].

Purdue Pegboard (PPB)

Thirty seconds are allowed for transferring as many pins as possible from bins into separate holes with the right hand alone, left alone, and both simultaneously. Another task involves the same transfer with the additional assembly on the inserted pins of washers and collars using both hands alternately, allowing 60 sec. Score is total achieved for 3 repeated trials [18].

Pursuit rotor

Employing a standard rotary pursuit apparatus (Lafayette Instrument Co., No. 2230A) subjects using a metal tipped stylus attempted to keep contact with a penny-sized metal disc rotating at 60 rpm. The total contact time was automatically measured (by an attached Lafayette Stop Clock). Following three practice trials for each hand at increasing speeds (15, 45 and 60 rpm) subjects were given 10 consecutive trials of 15 sec each with each hand. Left hand always followed the right after an interval of 2 min. Score is the average contact time for 10 trials [19].

Finger tapping

With index fingers subjects tap as rapidly as possible a pair of standard telegraph keys calibrated for 250 gr force and a travel of 4 mm. Six trials of 10 sec each were given with each index finger separately and to both simultaneously. In a fourth task subjects tap with both hands alternately. Number of taps recorded by a mechanical counter constituted the score [20].

Arm tapping

In an apparatus described by Wyke [21] subjects tap back and forth as rapidly as possible on 2 metal plates, 10 cm square, and mounted 7·5 cm apart in a sagittal plane. Three successive trials of 15 sec each are performed with each hand separately and with both synchronously. In a fourth condition the two hands tap simultaneously but move in opposite directions. Score is the 3-trial average number of taps for each task.

Pantograph tracing

This test requires interdependent bimanual control. Manipulating a standard pantograph with both hands patients trace a course inside a predrawn, double-line star without going outside the printed lines. Performance is scored as 5-trial average for errors (deviations outside the printed star boundaries) and time taken to complete the pattern [22].

Bilateral crank turning

In this test interdependent bimanual control is also required but to a finer degree than in Pantograph Tracing. The exact same two-handled, enlarged "Etch-a-Sketch" type, apparatus described and illustrated by Preilowski [6] was used. The task is to trace a single line with a built-in pen within a narrow double line 19 cm long set at 112·5° angle. Score is number of errors (touching the sides of the preprinted track) and time taken to complete each trial. This test was given only to complete commissurotomy patients since the partial patients were found by Preilowski to be unimpaired in the initial learning stages.

Buttoning.

With both hands subjects fastened a vertical row of small buttons (each 1 × 1 mm) through button holes set 1 mm apart. Score is time taken to complete the task. This test was administered in order to measure speed of performance of a skill well established prior to surgery.

Clinical apraxia tests

Subjects were asked to perform 63 different gestures to spoken commands. Sixteen were taken from DE RENZI *et al.* [23]: Ideomotor apraxia—make sign of the cross, salute, wave goodbye, threaten somebody with your hand, show that you are hungry, thumb your nose, snap your fingers, indicate that someone is crazy, make the letter O with your fingers. Ideational apraxia (the following objects were picked by the subject to demonstrate their use)—hammer, toothbrush, scissors, revolver, eraser, lock and key separated, match and match box.

Forty-seven were taken from BROWN [24] as follows: Non-representational movements—place hand under chin, place hand in front of nose, touch index finger to ear, put hand behind head, touch thumb to forehead. Facial praxis—blow out match, sip on straw, protrude tongue, cough, sniff flower, close your eyes, lick upper lip, puff out cheeks, whistle, wrinkle your nose. "Intransitive" movements—salute, scratch head, throw kiss, indicate full stomach, beckon, hitchhike, make fist. "Transitive" movements—brush teeth, shave, comb hair, drink with spoon, file fingernails. Leg praxis—stamp out cigarette, press on gas pedal, tap foot, kick a ball, slide foot in slipper. Whole body—walk backwards, stand like a boxer, golfer, batter, shovel dirt, jump, squat, bow, shrug. Bilateral hand movements—play piano, clap, circle hands in air, pray, jump rope.

In all of the above tests the patients were asked to perform the entire series first with the left and then with the right. All initial instructions are given without demonstration either by pantomime or through pictures. For every item a response is "correct" if it is immediate or preceded by slight hesitation and "incorrect" if protracted and irrelevant.

To test for dyscopia (constructional apraxia) patients were asked to copy 7 geometric figures first with the right then with the left: square, triangle, hexagon, cube, diamond, cross, simple nonsense figure. Dysgraphia was tested by having the patient write to dictation first with the left and later with the right: mother's first name, "Today is Friday", "baseball", "car". Dysgraphia and dyscopia have also been investigated in the short-term by BOGEN [5].

RESULTS

General

The mean raw scores obtained on all dexterity tests are listed in Table 2 along with the corresponding percentiles based on scores of the normal subjects. The level of performance with regard to speed was low throughout with most individual patients' scores falling below the 10th percentiles. In spite of the low ratings on scores for speed the performance was remarkably free of noticeable clumsiness or incoordination on the majority of these tests. The patients generally displayed fine motor precision in both the unimanual and bimanual tasks.

Minimal left-sided dyspraxia, of the ideomotor type, moderate right-hand dyscopia with marked left-hand dysgraphia were evident in all complete commissurotomy patients except LB. In the partial commissurotomy subjects general dyspraxia was not detected but right-hand dyscopia and left-hand dysgraphia were observed in one patient, DM, comparable to that observed in the complete cases.

No difficulties were noted with the initiation of necessary movements on any of the tests. However, there were difficulties with continued maintenance of the correct movement patterns under some bilateral conditions. This was most obvious on tasks requiring rapid asynchronous motion (alternate Arm Tapping and alternate Finger Tapping) and bilateral interdependent control (Pantograph Tracing and Bilateral Crank Turning). In the former type of movement only subjects LB, NF and DM could maintain correct motion for longer than the first 5 sec, albeit at a subnormal rate. In other types of alternate bilateral motion (Assembly in PPB and Turning in MRMT) where object manipulation was involved, good continuous bimanual control over 30 sec in duration was seen in all patients.

In tasks measuring bilateral interdependent control severe impairment was evident. This was most pronounced in Bilateral Crank Turning where only the three youngest cases (LB, AA and CC) were able to cross-integrate motor output from both hands to trace a

Table 2. Mean raw scores and the equivalent percentiles based on the performance of normal subjects

Test:	$\bar{X}$:	SD:	Range	Percentile
PB-MWS				
Assembly	9′54″	2′55″	7′58″–17′04″	2·3
Disassembly	4′34″	1′12″	3′34″–7′10″	·62
CSPDT				
Part I	12′48″	4′39″	8′48″–22′55″	< 1
Part II	15′17″	5′18″	10′51″–28′09″	1
MRMT				
Placing	5′54″	1′31″	4′30″–8′07″	< 1
Turning	5′27″	1′15″	3′55″–8′01″	2
Displacing	4′30″	1′15″	3′22″–6′55″	< 1
One-hand	8′06″	2′49″	5′39″–13′19″	< 1
Two-hand	4′34″	1′11″	3′07″–6′46″	< 1
Stromberg				
Test 1	2′10″	0′43″	1′35″–3′37″	< 5
Test 2	2′11″	0′39″	1′34″–2′22″	< 5
Rotary Pursuit				
Right-per trial	1·60″	1·18″	·04″–2·98	< 1
Left-per trial	1·31″	0·92″	0″–2·43″	< 1
Star Tracing				
Time	1′30″	0′15″	46″–2′58″	< 1
Errors	3·93	4·66	0–19	< 1
PPB				
Right hand	37·00	10·66	21–55	4
Left hand	36·75	6·52	27–47	7
Both hands	28·38	6·63	17–38	5
Assembly	73·38	11·25	49–86	6
MaQTMA				
Tracing	13·75	4·95	6–20	8
Tapping	21·75	10·07	10–34	< 1
Dotting	11·50	2·27	7–14	< 1
Finger Tapping				
Right hand	57·38	10·38	41–72	2
Left hand	53·50	10·21	36–67	< 1
Both hands—simultaneously	52	11·03	34–69	< 1
Arm Tapping				
Right hand	59·13	10·16	41–71	6
Left hand	50·75	5·52	38–54	2
Both hands—simultaneously	51·75	6·76	43–60	3

single line. Although qualitative and quantitative performance remained clearly below normal, by the third trial the number of errors was reduced from a mean of 8 to an average of 5. Time scores for this task meanwhile improved only slightly with repeated trials.

In Pantograph Tracing much difficulty in the initial 1–3 trials was evident in the three older complete commissurotomy patients (NG, NW and RY) but only moderate difficulty was experienced by the three younger subjects (LB, AA and CC) and the two partial cases. With the exception of RY and NW all patients improved noticeably with practice on this task in terms of both speed and errors.

Unimanual vs bimanual performance

When scores, given in Table 2, for unilateral and bilateral performance on the same test (Finger Tapping and Arm Tapping) are compared, the results are found to differ from those of normal subjects in whom as a rule there is a definite reduction in speed for the bilateral condition on these tasks [21]. The patients' scores on bilateral rapid tapping movements by contrast were only slightly slower than those for either hand alone, generally matching in trend those reported for other brain lesioned patients [21]. On test PPB, however, where more refined and precise motion was required, bilateral speed was markedly below that of unilateral performance. Generally, under conditions of simlutaneous bilateral motion the asynchrony was slight and no greater than in normals.

As with normal dextrals, the right hand was faster than the left in unilateral tests where no extracallosal damage was involved. Also in conformance with the normal [25, 26] and brain-injured trend [21], the speed of the right hand during bilateral tapping, as compared to unilateral tapping, was diminished proportionally more than that of the left. Left-hand speed diminished in some cases, but increased or remained unchanged in others. Normal subjects described show only diminished or unchanged speed.

Finger dexterity and precision

Clumsiness, absent on the whole, was apparent in the CSPD Test Part 1, particularly in the use of tweezers by the right hand. The clasped pins were frequently dropped whereas equally small pins were effectively handled with the fingers on PPB in both unilateral and bilateral conditions. Another tool, a small screwdriver (Part 2 of CSPD Test), was used much more skilfully.

Although precision in rotary pursuit was poor (see Table 2) there was moderate improvement after several trials with the right hand but none or only slight improvement with the left. This is in contrast to normal subjects and other brain lesioned subjects in whom there is strong transfer of learning from right to left [19]. The difficulties on rotary pursuit were demonstrated by all patients regardless of age or extent of surgery.

Pantograph Tracing showed consistent improvement but the traced pencil line remained wavy and irregular. The patients exhibited a visible strain in this test not evident in normals, and the tracing of normal control subjects was much straighter and less erratic. When questioned about their excessive curlicues most patients attributed it to lack of adequate control over the left hand. One patient, NG, complained that she felt her two hands were fighting for control of the pantograph handles. Similar tense strain and exceedingly erratic tracings were also observed in Bilateral Crank Turning [6].

Buttoning, which served as a measure of a skill well learned prior to surgery, appeared to be performed smoothly but the average speed for the patients was almost $1\frac{1}{2}$ times slower than that of normals.

Conventional apraxia tests

Distinct symptoms of left-sided dyspraxia to verbal commands were still present at this time, 6–10 yr after surgery, in all the complete commissurotomy patients except LB. As is characteristic of the commissurotomy subjects, the apraxic performance blocks were very promptly overcome, however, following demonstration of the correct response by the examiner or after the same response was first made correctly by the patient's right hand. Thus the order of hand use was critical for performance. Once a movement had been made correctly by the right hand and observed visually by the right hemisphere the executional capacity was no longer confined to the left hemisphere and direct control of the left hand by the right hemisphere became possible.

The praxic disturbances were mild and evident only in failures on ideomotor and non-representational types of test items. Incorrect responses were characterized by confused, abortive or irrelevant gestures. Failures were predominant in movements requiring use of single digits of the hand as in "hitchhike", "beckon", "touch forehead with thumb", etc. Correct responses with the left hand were generally less refined and somewhat slower than the same responses made with the right hand. No apraxia was observed in ideational, facial, and whole-body movements.

Poor copying of geometric figures by the right hand was most pronounced on the cube and hexagon. In cube copying the right hand failed to reproduce the spatial part, drawing only a square with superfluous straight lines, as in the early observations [5, 27], and the hexagon was copied with only four or five sides. Errors in left-hand writing involved letter substitutions, omissions, and perseveration. For patients, NG, NW and RY cursive script was impossible with the left hand and printing was used instead. At the same time these patients like the others had no difficulties in copying printed words.

Tests for underlying factors in dyspraxia

A special scleral lens technique for lateralizing visual input [28] was used to check some of the underlying mechanisms that might be responsible for the left-sided ideomotor dyspraxia. Two patients (LB and NG) were tested who at the time had been fitted with the scleral lens. To check the right hemisphere's ability to copy non-verbal postures and also the extent to which the left hemisphere can control fine finger and hand postures of the ipsilateral hand the following tests were given: twenty-four drawings of hand postures [29] were presented to the left and right hemispheres, separately, and the subject was asked to duplicate the postures with each hand. Each hemisphere readily duplicated hand postures 100% correctly with the contralateral hand. Ipsilateral finger control also was found to be surprisingly effective especially in the left hemisphere which scored 80–90% correct with the right hemisphere getting about one-fourth correct. The results indicate that direct visual monitoring gives better ipsilateral finger control than is obtained through spontaneous voluntary auditory or linguistic channels, and suggest possible involvement of the left hemisphere in the correct left-hand gestures of the ideomotor trials.

To determine whether lack of comprehension of the verbal instructions in the right hemisphere might be a factor, the examiner read aloud nine verbal commands from the ideomotor battery and for each the subject had to use his left visual field and left hand to point to one out of four pictures that correctly depicted the verbal message. Pointing responses were found to be on the average 80% accurate indicating that lack of comprehension in the right hemisphere, *per se*, was not a major factor in causing the observed dyspraxia.

DISCUSSION

Long-term effects of cerebral commissurotomy were assessed in 8 patients $4\frac{1}{2}$–$9\frac{1}{2}$ yr after surgery by applying tests for conventional dyspraxia and mainly a series of standardized tests for manual dexterity and intermanual co-ordination. In contrast to the apparent normality of the motor co-ordination in most of the dexterity tests, and in preoperatively learned skills generally, all percentile scores based on speed were markedly subnormal. This was generally true even with respect to the dominant hand and highly practiced skills (fastening buttons) learned prior to surgery. Mild forms of dyspraxia, dyscopia and dysgraphia were still present in varying degrees, and severe qualitative impairments were evident in tasks that required bimanual interdependent control where the movements of one hand depended on the sequencing of movements in the opposite hand.

The reduced scores for speed in both unilateral and bilateral conditions averaged 35% below those reported for various types of brain-lesioned patients who were largely free of primary motor and sensory deficits [19, 21, 22]. This was true for the partial as well as for the complete commissurotomy patients even when the scores of those patients with known pre- and postoperative motor deficits were excluded from the comparison. Since all patients in the present study were taking anticonvulsive medication, albeit for many years, the possibility that the slowed rate may be attributed, at least in part, to the drugs cannot be ruled out. The decline in tapping rate in bilateral as compared to unilateral performance favours the conclusion of KREUTER *et al.* [30] that the two cerebral hemispheres are not independent control systems for left and right hands but rather contain integrated controls for bilateral activities that limit the double task capacities of commissurotomy patients (see also TREVARTHEN [31] for discussion).

The essentially normal co-ordination exhibited in the synchronous symmetrical bimanual tasks stands in sharp contrast to the severe impairments observed with tests requiring interdependent bimanual movements (Pantograph Tracing and Crank Turning) and rapid alternate bimanual tapping. Similar disturbances were seen in an earlier study by PREILOWSKI [6, 7] and related motor difficulties have been observed also with other patients with callosal lesions [32]. Although earlier initial observations [7] suggested that complete commissurotomy patients were unable to perform the complex crank turning task, the younger patients (AA, LB and CC) were able to do so in this study following experience with the pantograph and with special encouragement, and improvement with practice was evident. However, there was no improvement in rapid alternate tapping or in alternate pronation–supination with the forearms. No unusual marked difficulties with any bimanual activities were noted in the partial commissurotomy patients, in keeping with Preilowki's observations on initial learning in these patients, nor did any of the patients studied exhibit a definite unilateral diadokokinesia as reported by AKELAITIS *et al.* [33]. In the case of the bimanual alternating movements and interdependent co-ordination it appeared that the patients could always initiate the correct motion for the first two or three trials but had a problem in maintaining it. In tasks where maintenance was possible there was improvement with practice.

Practiced skills learned prior to surgery that also required similar interdependent manual co-ordination or alternating control show, by contrast, little or no qualitative disruption. It would thus appear that extensive over practice leads to a quite different mode of cerebral organization that becomes independent of the neocortical commissures, perhaps by contraction to lower (cerebellar?) levels, or by reinforcement such that control is possible from within a single hemisphere.

Conflicting and dissociated acts of left and right hands, seen primarily in an earlier patient (WJ) with extensive pre-existing right hemisphere damage and in early postoperative stages in others (NW and RY), have been ascribed [34, 35] to lateral or hemispheric differences in psychological states or intent. The present findings suggest a simpler basis in terms of motor control disturbances at an essentially efferent and reflex level rather than in cognitive or emotional states. Forced reflex movements and other largely involuntary responses seem now to offer the most parsimonius interpretation.

The dyspraxic symptoms observed here were reportedly absent in the commissurotomy patients studied by AKELAITIS *et al.* [33], but similar symptoms have frequently been described as a result of cerebral lesions that involve callosal fibre systems [36–39]. Symptoms in the present patients differed from some previous accounts [23, 24, 40, 41, 42] in that the test movements were not dyspraxic under conditions of nonverbal imitation, a difference possibly attributable to a lesser degree of extracallosal brain damage in the present subjects.

Previous explanations of dyspraxia have stressed the role of the left hemisphere in volitional control of motor activities (see GESCHWIND [37] for review). The presence in the present subjects of various right-hand dyspraxias like dyscopia and constructional apraxia for Kohs Block Designs [27] indicate that cerebral volitional control may work through the callosum in the reverse direction as well, i.e. from the non-speaking to the speaking hemisphere in performances for which the former is more specialized. As a general conclusion it would appear that volitional motor control of the ipsilateral hand, in either hemisphere, normally involves regulation not only through direct ipsilateral pathways but also through callosal fibres to the contralateral motor centres of the opposite hemisphere.

In view of the demonstrated high auditory vocabulary comprehension of the right hemisphere [43] the left sided ideomotor-type dyspraxia in the five complete commissurotomy patients would seem to indicate a weakness within the right hemisphere in associations between verbal comprehension and motor channelling. Unimpaired imitation of the same and more refined gestures following visual observation of the performance by the examiner or by the patient himself on the other side would seem to rule out lack of motor control from the right hemisphere. Lack of comprehension of the command seems to be excluded by the observation that the incorrect gestures of the left hand or leg were not merely chance responses but often had one or more elements of the motor sequence correctly executed. In addition, the separate control trials lateralized to the right hemisphere testing aural comprehension of the same verbal commands confirmed that right hemisphere understanding of the instructions was largely intact. The conclusion that the visual and motor components separately are adequate in the right hemisphere is supported further by the absence in the same subjects of ideational apraxia requiring association between visual recognition of the object and its proper use.

Additionally, the dyspraxic left-hand gestures in the presence of the normal preservation of right-hand responses indicate an inefficient functional associaton between the language comprehension centres of the left hemisphere and those for fine ipsilateral motor control of the left hand. Motor control of the left hand through the language centres of the left hemisphere must be distinguished apparently from control by visual monitoring in the same hemisphere. Fine ipsilateral motor co-ordinations were obtained in the separate control trials involving the imitation of visually presented postures. The deficit seems to be a confusion in high-level functional integration between language comprehension and its volitional motor expression in the ipsilateral hand. We may infer that normally such control is achieved via the callosum and contralateral motor centres, and that, with the commissures sectioned, motor expression of highly lateralized tasks, like carrying out spoken commands, writing, or the copying of visual designs, will be inefficiently executed with the hand that is ipsilateral to the controlling hemisphere. This is consistent with the fact that motor tasks not dependent on hemispheric specialization, as in the majority of the visuomotor dexterity tests, did not show similarly marked praxic disturbances.

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Résumé :

On a étudié les effets à long terme de la commissurotomie cérébrale sur la coordination motrice et la dyspraxie chez 8 malades ayant subi une commissurotomie complète ou partielle, 6-10 ans auparavant. On a comparé leur performance à une série d'épreuves standardisées de coordination motrice et de dextérité manuelle avec les normes établies préalablement. Bien que la performance apparaisse au plan qualitatif essentiellement intacte à la plupart des tests, les scores de rapidité étaient de façon cohérente au dessous de la normale et également inférieurs à ceux rapportés pour les malades atteints de lésions cérébrales unilatérales diverses. Dans certaines tâches bimanuelles exigeant un mouvement alternatif rapide et un contrôle interdépendant, on constatait des troubles graves à la fois sur les plans qualitatif et quantitatif. En outre, chez les malades avec commissurotomie complète, on observait une dysgraphie nette et dyspraxie légère de type idéomoteur du côté gauche ainsi une dyscopie modérée à droite et ceci jusqu'à 10 ans après la chirurgie. De ces résultats, il ressort que la communication interhémisphérique devient particulièrement importante pour la sortie motrice si l'épreuve réclame une coordination intermanuelle complexe ou une spécialisation hémisphérique avec contrôle ipsilatéral.

Deutschsprachige Zusammenfassung:

Bei 8 Patienten, die sich sechs bis zehn Jahre zuvor einer kompletten oder partiellen Kommissurotomie unterzogen hatten, wurden die Auswirkungen der cerebralen Kommissurotomie auf motorische Koordination und Dyspraxie untersucht. Die Leistungen bei einer Serie standardisierter Tests zur motorischen Koordination und Händigkeit wurde mit Normwerten verglichen. Obwohl die qualitative Leistung bei den meisten Tests im wesentlichen ungestört wirkte, waren die Leistungen in Bezug auf Geschwindigkeit übereinstimmend unter der Norm und auch unter den Ergebnissen, die von Patienten mit verschiedenen unilateralen Hirnläsionen erzielt werden. Bei gewissen bimanuellen Aufgaben, die rasche wechselnde Bewegung und gegenseitige Kontrolle verlangen, zeigten sich schwere qualitative und quantitative Beeinträchtigungen. Außerdem waren ausgeprägte Dysgraphie und leichte ideokinetische Dyspraxie auf der linken Seite und mäßige Dyskopie auf der rechten Seite bis zu 10 Jahren nach der Operation bei den Patienten mit kompletter Kommissurotomie nachweisbar. Nach diesen Ergebnissen scheint die interhemisphärische Kommunikation besonders wichtig für den motorischen output zu sein, und zwar insbesondere bei den Aufgaben, die komplexe intermanuelle Koordination oder hemisphärische Spezialisierung mit ipsilateraler Kontrolle verlangen.