

TWO-POINT DISCRIMINATION TEST

A Valuable Part of Hand Surgical Rehabilitation, e.g. in Tetraplegia

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ABSTRACT. In assessing the prospects for surgical and other kinds of rehabilitation in tetraplegia and stroke patients the two-point discrimination test, correctly performed by experienced examiners, is of great value. Valid and repeatable results depend on exact technique and proper tools. There is a firm correlation between the thresholds of two-point discrimination on the pulps of the fingers and the accuracy of position sense at the metacarpophalangeal and interphalangeal joints. Microneurography has shown that cutaneous receptors have proprioceptive as well as exteroceptive functions. Thus the two-point discrimination test can be used as a measure of proprioceptive function. The results can be expressed numerically. A two-point threshold < 10 mm on the pulp is a valid measure of useful finger proprioception. It also shows tactile gnosis, necessary for precision sensory grips.

Key words: testing of sensibility, surgical hand rehabilitation, tetraplegia, stroke.

The importance of afferent as well as efferent innervation in motor control was 1854 proved by Charles Bell (2) in experiments on the anatomically separate sensory and motor nerves of the face. "Now, if this nerve of motion be cut and loose its function, the animal puts its lips to the grains it feeds upon, but cannot gather them. So also, if the nerve of sensation be injured, the animal presses its lips to the food, but wanting the sensibility by which the motion of the lips should be directed it does not gather them."

Afferent impulses from muscles are known to provide unconscious servo-control of postures and movements by proprioceptive reflexes. Afferent impulses are also essential for conscious proprioception—our awareness of the positions and movements of our hands and arms and of other parts of the body. Until recently the only proprioceptors were thought to be those of muscle spindles, tendon organs and joints. The afferent innervation of the skin was thought to be

purely exteroceptive, responsive only to tactile stimuli from the external environment.

The experience of hand surgeons, however, has shown that conscious proprioception and intact manipulative function are impossible in the absence of a proper afferent innervation of the skin in spite of muscle function.

A young man was stabbed from behind in the neck and rendered partially tetraplegic. Fourteen months after wounding, the motor loss in his right arm was limited to most of the intrinsic muscles of the hand. The long finger extensors and flexors were functioning well. The elbow muscles including pronators and supinators were intact. But there was a loss of all qualities of sensibility in both hands. This man had no conscious proprioception in hands, wrists and elbows in spite of so many muscles and tendons active.

Moberg (9) found 1962 that the Weber two-point discrimination test (2PD) was the only test used in neurology which gave a reliable approximation of the quality and functional value of the sensory component in hands, who had got different degrees of recovery after a nerve suture. In 1954 Seddon et al. (14) had found that other neurological tests were erroneous for this purpose.

The conscious proprioceptive function in this region, in the few instances where it has been discussed, was earlier examined only by the classic passive extension and flexion of finger joints and this was in my surgical work unsatisfactory. This paper presents a reliable and reproducible method for measuring 2PD thresholds. Its results are shown to correlate well with those obtained by quantitative testing of position sense in fingers. Its practical importance is for planning of reconstructive surgery and postoperative rehabilitation. Prognosis depends on the patients ability to relearn lost voluntary actions and to learn totally unfamiliar ones, e.g. when an extensor muscle has to work as a flexor. Much conscious learning requires

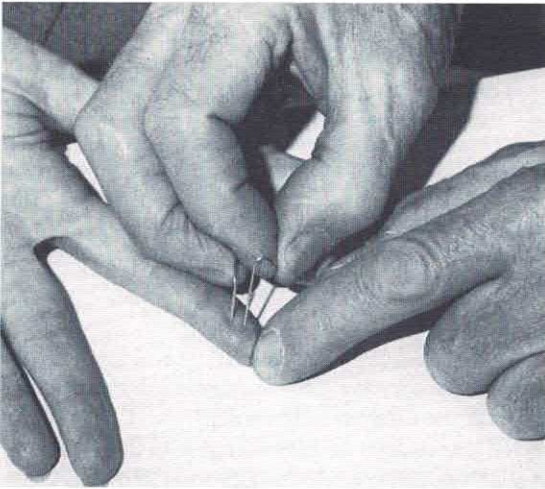


Fig. 1a. In order to avoid every unwanted and disturbing motion or vibration, the part of the hand to be examined must be steadily immobilized on a firm support. For the examiner's hand the same is also a must. For the same reason long arm instruments must be discarded.

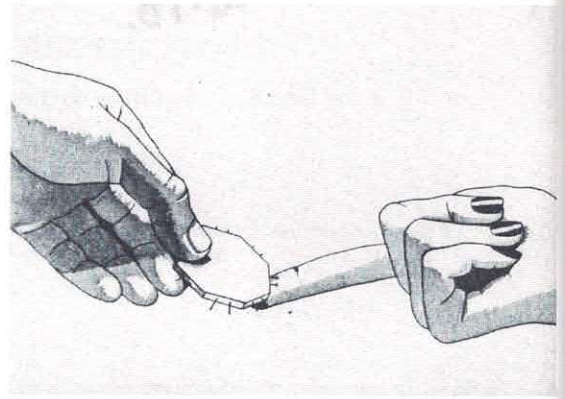


Fig. 1b. When, as often advertized, the test is performed in the way shown here, no reliable results can be obtained. Examiner and examinee will both produce disturbing motions.

feedback from cutaneous receptors as well as from classical proprioceptors.

This report has two parts: 1) to demonstrate a reliable and reproducible way to test the 2PD and 2) to show the value of this test for determination of proprioceptive hand function.

1. THE 2PD TEST

Method

The 2PD test was originated by Weber (18) but was by him never used for testing sensibility, only to demonstrate a tactile illusion. In neurology it has had limited use. But in hand surgery it has been widely accepted as a way to evaluate regained sensibility after nerve suture, grafting and after replantation. It has also been severely criticised (Moberg (10), Bell & Buford (3), and by many other authors) due to the great importance on the results of the technique used (Fig. 1). Reliable and repeatable results can, however, be obtained.

Examiner and examinee must both be comfortably seated with their hands stabilized against a firm support. As tool an instrument was made of a paper clip with a wire diameter of 0.8–0.9 mm. Some brands have a small barb, where the wire has been cut. This is easy to remove. The testing must avoid disturbing movements just as this is necessary in performing microsurgery. The application force should be about

10 g as tested out by a small balance constructed for that purpose. This corresponds with the force producing the very first small "blanching" around the prongs.

The examinee was told to say "one" if he felt one point and "two" if two were felt. They were also free to say "I can't tell". Seven correct answers out of ten were accepted as valid for determination of the threshold. Usually the answers were delivered without doubt. There was some times a difference between confident and hesitant replies but this was obviously hard to quantify.

To show that the test, performed as described, could give reproducible results the hands of normal healthy subjects as well as of tetraplegic patients were examined twice by the same examiner, the author. The interval was at least 48 hours up to several months. These 2PD tests were only performed on the volar aspect of the digits but usually on all segments (Fig. 2), starting with the pulps. Only in a few fingers

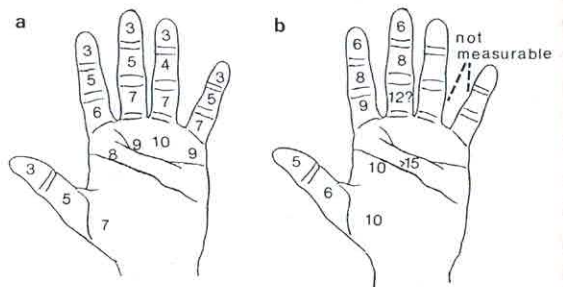


Fig. 2. (a) Volar distribution of the 2PD values in a normal hand, and (b) in a fairly good tetraplegic hand.

Table I. *Validity of the two-point discrimination test in normal individuals*

The same areas were tested twice by the author

Original 2PD values	No. of tests	No. of differences over 1 mm found in second test	
		2 mm	3 mm (+ or -)
3-5 mm	190	2	1
6-8 mm	126	11	0
9-10 mm	24	3	1

on tetraplegic patients the two tests were performed by different examiners.

Different results can be due to different concentration at the two sittings. Variations in thickness of the skin are an important factor which can be a result from a few days of unaccustomed hard manual work and can raise the 2PD threshold. An increase of 1-2 mm is not unusual, an increase of 3 mm is, however, exceptional. Longitudinal orientation of the points will often give values 1 mm higher than those measured in transverse orientation, but such small variations are not of practical interest.

Differences between results obtained at the first and second session will naturally be greater when the 2PD thresholds are higher. No attempts were made to go below 3 mm as lower values are rare (1) and of no interest for the present study. Rapid and confident responses during the testing of finger pulps up to this level, 10 mm, shows that tactile gnosis is adequate for precision sensory gripping by the digit (Moberg, 1962).

Fig. 2a represents a hand in a normal subject with the typical 2PD thresholds in the different volar fields described. Accordingly, in this hand, 10 test results were between 3-5 mm, 6 between 6-8 mm and 3 between 9-10 mm. In some other hands, due to obvious callosities, all volar fields were not tested, but always the pulps. Fig. 2b shows the volar field in a fairly good hand in a tetraplegic patient.

The validity of the 2PD testing in normal digits as well as in digits of tetraplegic patients

Table I illustrates the variation between the two tests by the same examiner, the author, on normal subjects. Table II shows similar thresholds for the tetraplegic patients.

In order to show that similar results can be ob-

Table II. *Validity of the two-point discrimination test in tetraplegic patients*

The same areas were tested twice by the author

Original 2PD values	No. of tests	No. of differences over 1 mm found in second test		
		2 mm	3 mm	4 mm (+ or -)
3-5 mm	89	4	1	0
6-9 mm	54	15	3	0
10-15 mm	37	13	6	1

tained also by other examiners such test values are given from digits of tetraplegic patients obtained by three other MDs, trained by the author in this examination. The repeated examinations of the same patients were performed usually with intervals of a number of months, sometimes years, but all in cases regarded as stable (Table III).

Some tetraplegic patients start to be less certain in their responses at 2PD values 1 or 2 mm lower than normal subjects. It is only in a limited number of patients that one has attempted to go down to 3 mm, and from 10 mm one has often passed over to 12 mm and from there to 15 mm.

It has thus been shown that the 2PD test, performed with the technique indicated, gives repeatable and reliable results both in normal and in tetraplegic subjects.

2. CORRELATION BETWEEN 2PD AND POSITION SENSE

During the past 30 years I have found it useful, in surgical reconstructive work, on patients with tetra-

Table III. *Validity of the two-point discrimination test in tetraplegic patients*

The same areas were tested twice by three different physicians, not by the author

Original 2PD values	No. of tests	No. of differences over 1 mm found in second test		
		2 mm	3 mm	4 mm (+ or -)
3-5 mm	54	4	-	-
6-9 mm	13	4	1	-
10-15 mm	15	2	2	2

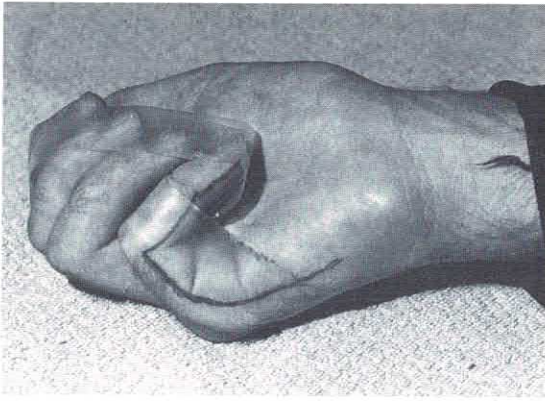


Fig. 3a. A finger fixed with tape.

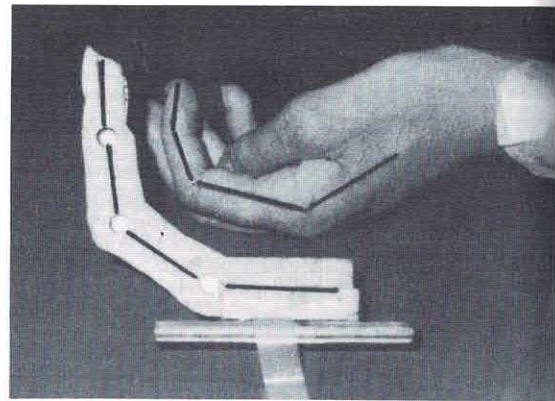


Fig. 3b. The paper finger photographed at the side of the tested finger. Position differences can be measured.

plegia, stroke, plexus lesions and similar cases, to base surgical indications upon the assumption, that evaluation of conscious proprioception, as well as of tactile gnosis, could be made by a single test, the 2PD. The advantage of the 2PD test is that it is more exact than the classical one, it can be applied to segments for segment of the digits, and the results can be expressed numerically.

Stataesthetic and kinaesthetic sensations no doubt have most receptors in common, even if the quantities of slowly and rapidly adapting receptors might be different. Therefore it should be possible to obtain useful information by examining only the stataesthetic one. This, the perception of position, has been chosen as the easiest to test. The great majority of patients with tetraplegia cannot move their fingers actively at all and the testing is not disturbed by active movements, but often they still retain position sense.

Method

The position sense was tested by placing the joints of one finger in random positions of flexion and extension. The position was maintained with as little tape as possible (Fig. 3a). The positioning was completed in less than 30 sec. Vision was excluded by a screen which did not touch the hand. The subject then had to imitate the position of the stationary finger joints by adjusting a paper finger with movable joints (Fig. 3b). If he could not do this with his other hand, e.g. tetraplegic, the examiner had to make the adjustments by following his examinee's instructions, e.g. more flexion in one joint, more extension in another until the examinee was satisfied. When possible the

paper finger was photographed beside the real finger and the differences in the angles were measured on the photo. Joint contractures, lack of rotation or other similar difficulties frustrated this method, why the angles of the real and the paper joints were measured directly. The first method was more often used in digits with 2PD better than 10 mm, the second in those with less good sensibility. In normal subjects, unexpected and considerable differences between actual joint positions and the subjects perception can occur. One explanation is that the subject wanted to be more sure of the correctness of his perception and so hesitated in delivering his response. In the meantime the memory of the motion that brought the joints into position had faded. A rapid decision is therefore important. Serious mistakes, however, are few and when the test is repeated a normal result is the rule. In the results below no such repetitions are included. In patients whose digits were totally without volar sensibility many answers were within the limits of normal error for normal digits, just as should be expected when only a guess was behind the answer.

To obtain control values of the correlation between 2PD and position sense, five young healthy males were chosen. All had normal 2PD with values of 3–5 mm in the pulps of all fingers. Their position sense values were compared with the same from twenty-four fingers in sixteen tetraplegic patients. They all had the same 2PD values as the normal ones. In a few of these fingers from tetraplegic patients more than one test was made. Possibly extreme values here could inaccurately change percentage figures. To exclude this only the first test value from each finger was used.

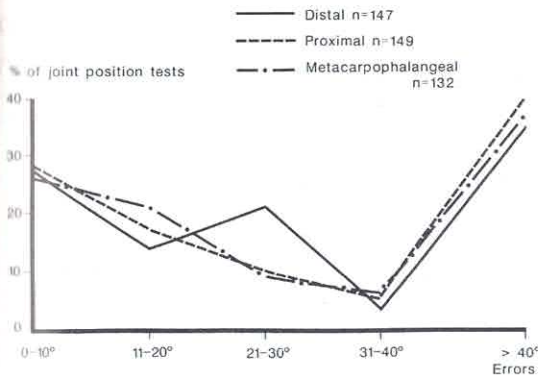


Fig. 4. Comparison between the three finger joints (DIP, PIP, and MP). From averagely similar number of position tests in tetraplegic fingers, random observations, the differences between the given joint position and the subject's evaluation of the same (errors) were brought together in groups of 10 (0-10, 11-20 etc.). The percentage groups were for each joint plotted in a separate curve. No important difference between the different three joints is visible and therefore it has not been necessary to treat them separately.

When testing tetraplegic patients with increased 2PD values it was not found useful to record values determined more exactly than necessary for the clinical purpose. If 5 mm was undoubtedly present on the distal pulp it was not always tested if 4 or 3 mm worked.

The perceived and measured angles were obtained from the distal (DIP) and proximal (PIP) interphalangeal joints and from the metacarpophalangeal joints (MP). The different joints showed important differences. The range of movement is larger in the PIP and MP joints than in the DIP joint. More extensive deformation of the skin around the joints would supposedly be easier to feel. But another factor seems to work in the opposite direction: the more limited range of the DIP joint allows less chance for error. Fig. 4 shows the results from all three joints in the fingers of tetraplegic patients. No significant differences existed between them. Therefore all values from the fingers are included in the discussion below.

Results

Fig. 5 shows clearly that the 2PD pulp values of 3-5 mm correlates with equally good position sense values in digits from tetraplegic patients as in normal fingers.

No values from the thumbs are included here. The tests on this digit were not numerous and the thumb differs in many respects from the other digits. But they have been evaluated and no difference in princi-

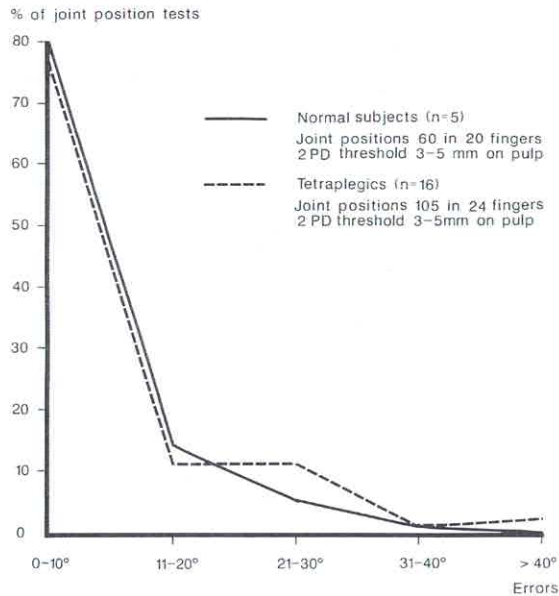


Fig. 5. Correlation between the two-point discrimination test and position test in normal subjects and in tetraplegic patients with normal 2PD in finger pulps.

ple has been found. This is of practical importance. Hands with for gripping useful 2PD (better than 10 mm) only in the thumb, the remaining four fingers without this, are in tetraplegia very common, even in majority. These hands can by surgery be given useful function.

By contrast to the digits with pulp values 3-5 mm the ones with thresholds over 10 mm show no position sense (Fig. 6). Some patients said firmly that they could not feel the positions of their fingers and the behavior of others suggested that they just wanted to be helpful and were trying to guess.

In order to define a clinically useful limit a series of trials was made in which various combinations were chosen from the whole series of correlations, not only with 2PD thresholds on the pulps but also on the other segments on the volar aspect of the fingers. From more than twenty selected combinations of 2PD and position sense a few only were found to be of significant value. Two of them are illustrated in Fig. 6. Curve A shows, as expected, that parts other than the pulp contribute to position sense, probably even more than the pulp. The pulp is certainly the easiest to examine, a great advantage in practical work. Testing the pulp will adequately represent the whole skin cover. But in amputation cases other skin areas have to be used and this is quite possible.

% of joint position tests

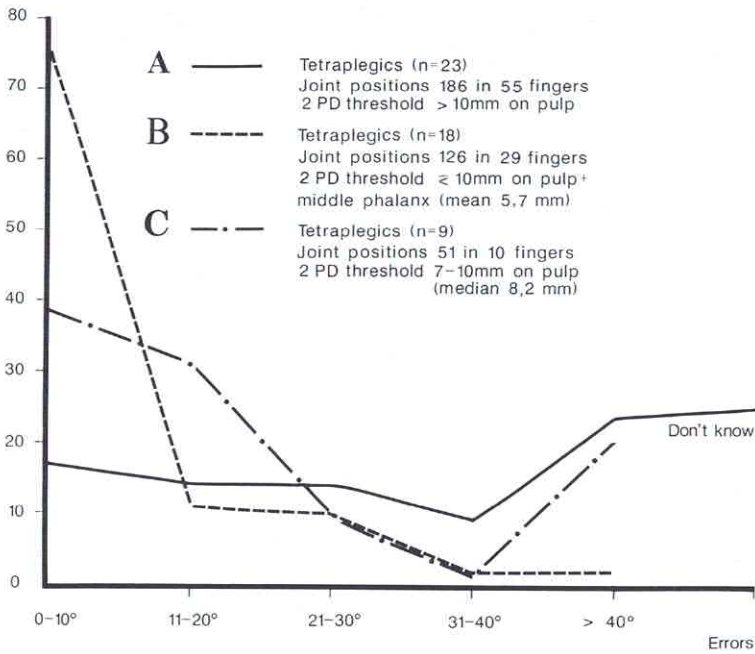


Fig. 6. See text, p. 131. One of the curves shows the same kind of correlation as in Fig. 5, here with fingers of tetraplegic patients with pulp 2PD worse than 10 mm. No position sense is present. The other two curves represent trials to close in limit values for clinical use as described in text.

Curve B was made to define the practical limit a step more. It is built upon the very unusual group with 2PD thresholds between 7-10 mm (median 8.2 mm) on the pulp. It can be seen that position sense is here less good than that shown in curve A but still there is a useful correlation. This trial clearly is showing that, at least in tetraplegia, there are so few cases with this range of values that there is no practical need to define the limit any further than has been done already.

The conclusion is that the 2PD test, performed as described here is a useful tool for determining position sense and probably also kinaesthesia in tetraplegic hands, valuable for surgical indications and for evaluation of prognosis in reconstructive work.

Stroke hands

2PD and position sense. With the same technical arrangements a pilot study, in several respects incomplete, but with interesting results, was performed on 32 elderly stroke patients. This study was incomplete as no closer neurological status was performed, nor was it in detail examined if the best arm was unaffected by the lesion. The patients, however, felt so.

Only pulp 2PD values were considered even if the examination included more. In some instances some

finger flexors were active. Therefore, small finger movements could not be excluded. The subjects were sufficiently well preserved mentally and linguistically to cooperate. All had reached a plateau of recovery. All had an efficient arm on the other side. No significant hand contractures were present.

The 2PD of the normal hand was tested first to control the cooperation. The practical usefulness of both hands was discussed and examined in detail.

Two different groups were distinguished with different levels of pulp 2PD and motor loss. In group I all 26 subjects had inadequate 2PD < 10 and also total loss of proprioception, even if a few had some active finger flexion. Those cases never used the affected hand for spontaneous activity. In group II, six subjects, all had 2PD of 5-7 mm present in most finger pulps. With eyes closed all could use this hand to pick up small objects.

As an example details will be given for one of these patients, an 85-year-old woman, who had had her stroke four years before the examination. Her 2PD in the pulps of the affected right hand was from the thumb to the little finger resp. 6, 7, 8, 7 mm, and not at all measurable. Twoposition tests were performed in the index as in the middle finger. In the three first-mentioned fingers there were in the 15 joint positions checked only a single error going up to 20 deg., all the

Table IV. Stroke hands, the better group

The errors in position tests in fingers with two-point discrimination up to 10 mm in pulps (see p. 133) in patients with stroke

Errors in deg.							
Joint	0-10°	11-20°	21-30°	31-40°	41-50°	51-60°	70°
DIP	21	5	5	2	3	-	-
PIP	21	7	1	1	1	1	4
MP	24	8	3	1	-	-	-
<i>n</i>	66	20	9	4	4	1	4
In %	61	19	8	4	4	1	4

rests were lower. In the little finger with unmeasurable 2PD there were positioning errors of 30, 40 and 80 deg.

The total position test results for fingers in this group with acceptable 2PD ($= < 10$ mm) are given in Table IV. Those without such a 2PD, the ones from group I, were spread out evenly over the whole field.

The conclusion of this limited survey on stroke patients is that the 2PD is a useful test also for this large group, as a reliable quantitative indicator of joint position sense.

An unexpected additional conclusion seems to be that the functional grip value of the stroke hand can be roughly evaluated with the simple and inexpensive 2PD test alone. Useless and expensive attempts to train such hands in the hope of getting more or less working capacity can in this way be avoided. Similar views on the training are recently given in an extensive study on stroke rehabilitation (17).

DISCUSSION

As useful motor action is controlled by afferent impulses, and as those from the skin are fundamental and cannot be more than partially replaced by impulses from other sources, mainly from vision, the 2PD test, properly performed, gives a very good clue to the prospects of surgical reconstruction. Quality of sensory function of this degree will not only contribute protective sensibility but also allow the digits knowledge about the kind of objects they have to deal with, to identify, to examine and to build up the learning and experience necessary for daily life and for special tasks.

Hand-arm function requires more than passive tactile gnosis and passive awareness of position (stat-aesthesia), it also requires perception of movements (kinaesthesia). The physiological basis for these conscious proprioceptive functions has been reviewed by Phillips (13). Microneurography has shown that the contribution of afferents from finger joints is very small. The contributions of musculotendinous afferents to kinaesthesia (over and above their automatic control functions) is negligible (11) though this has been disputed (8). The intensive contribution of afferent impulses from the skin can hardly fail to be important for kinaesthesia and for retraining of lost movements and the learning of new ones after the transfer of muscles in restorative surgery. No doubt kinaesthesia is aroused by stretching and compression of the skin when joints are moving, for example by dorsal elongation and volar compression when the finger is flexing. This deformation is the same as when the 2PD is performed and made it logical to see if not the 2PD could be used to determine also kinaesthesia. The skin creases may be regarded as "exo-skeletal joints" (13). Microneurography has revealed receptors in the finger skin which are excited not only by tactile stimulation but also by active movements of interphalangeal joints in the absence of any external contact (7). Also, it is here of interest that it has been shown by Hirasawa et al. (6), that there is a concentration of receptors at these locations. Such receptors can therefore be accorded proprioceptive as well as exteroceptive status. In the unique combination of explorative and manipulative performances of the fingers, with their refined motor control and dense cutaneous innervation, the distinction between proprioception and exteroception seems almost to vanish. The interesting studies performed by Westling &

Johansson (20) and Westling (19) have underlined this and also shown details and time factors well in correspondence with clinical experience. The correlation between 2PD and position sense in the hand is an empirical finding of practical value.

The rapid development of the surgical rehabilitation of the upper limb in tetraplegia has no doubt shown the way to help some of the patients also with other lesions to a better life quality. It was a new way to think, to involve the adequate way to examine the necessary quality of sensory function, which gave results. Earlier mistakes, such as to follow the experience from the totally different situation in polio, could be avoided.

Already, works by Bleck (4), Goldner (5), Swanson (15), Treanor (16), Waters (17), and others in different kinds of brain lesions have shown that arm-hand surgery has a definite role in rehabilitation. Certainly an expansion of these possibilities is to be expected. In plexus lesions it is true, that some little help can be given by microsurgery to the plexus itself, but much more is possible through surgical use of what is left in the arm. Again it is necessary to give up the feeling that motor function is the totally dominating factor. The motors need the lead of adequate sensory functions and only by bringing these two factors to cooperate can the patient be rehabilitated. Testing with the routine neurological methods has here hardly a value, the concept of "feeling" even less.

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