Inverse relationship between sensation of effort and muscular force during recovery from pure motor hemiplegia: A single-case study

G. RODE,*†‡ Y. ROSSETTI‡ and D. BOISSON†

†Hopital Henry Gabrielle, Hospices Civils de Lyon, B.P. 57, 69565 Saint Genis-Laval Cedex, France; and ‡Vision et Motricité, INSERM U94, 16 avenue du Doyen Lépine, 69500 Bron, France

(Received 5 November 1994; accepted 3 May 1995)

Abstract—A 39-year-old patient with a right pure motor hemiplegia, who complained of a striking sensation of effort when he performed a movement, was regularly examined during 4 months. The effort sensation and the force recovery have been measured during the execution of upper limb movements: shoulder antepulsion up to horizontal, supined elbow flexion up to horizontal and full hand digital grip. The subject was asked to realize a movement with the paretic arm and to concentrate on the felt effort; then he had to perform the same movement against a resistance with the healthy arm, until the perceived heaviness matched the effort sensation felt on the other side.

Recovery of force and evolution of effort sensation did not follow linear trends over time. The curves displayed significant steps and plateaus, which were mainly observed for the proximal movements. The steps tended to be clustered within a few days, consistent with crucial periods in the restoration process. Within these, significant reduction of the effort sensation and increase of the force were together observed. These critical moments of the motor recovery could be analyzed as the result of an improvement of the neural traffic in the internal capsule and an activation of specific structures involved in the representation of the force and effort.

Key Words: pure motor hemiplegia; motor recovery; rehabilitation; effort sensation; force; motor representation; capsular stroke; arm movement.

Introduction

There is in the literature a few self-observations of patients who reported their own sensations following a pure motor hemiplegia [e.g. 2, 23]. During the initial period, when the paralysis was total, they did not feel any sensation when they tried to move their paretic limbs. Later, when recovery had progressed and paralysis was less dense, each attempt to move gave the sensation that the hand or the foot was held down by heavy weights. One of the patients [23] reported his own sensation of effort as a sensation of resistance opposed to movement, as an "enormous burden which he could only lift with the greatest effort". Similarly, Brodal [2] spoke of his sensation as "some kind of mental energy" or even as "a real force of reinnervation". More recently, Gandevia [11] reported two similar cases. As previously related, a clear sensation of effort was noted from the beginning of motor recovery. The sensation of effort and the motor recovery seemed to be closely associated in their time course.

Such sensations may be defined as the subject's consciousness of his command to his muscles. Attempts have been made to rate these sensations according to the subject's perception of the heaviness of different weights as a measure of his muscular effort. For instance, the subject will choose increasing weights with one arm until the heaviness perceived with that arm matches the reference weight lifted by the other arm [13]. Head and Holmes [18] and Gandevia and McCloskey [1,3] showed in hemiparetic patients that weights were perceived as heavier when lifted by the weakened side. The same observation was obtained in normal subjects weakened with curare or muscular fatigue which supports the hypothesis that objects feel heavier when an increased command to the muscles is required [13].

The problem is to determine at which level this increased command might be read off [11]. In the four previous cases, which correspond to capsular stroke, the
relevant signal necessary to produce a sensation of effort could be generated at a subcortical level. This internal signal may reflect the increased neural traffic in the remaining uninterrupted corticofugal fibres [11]; the relevant signal of motor command can thus be centrally generated, involving the cortical motor areas and the cerebellum, as it is known after a cerebellar lesion, an overestimation of force is noted [1]. The participation of the afferent inputs is not essential for producing the sense of effort as the sensation persists after dorsal rhizotomy or spinal transection, but it is necessary for calibration and modulation of the signal of effort [14].

The central origin of the sensation of effort is confirmed by the fact that the same sensations are to be observed during a task of mental motor imagery [7]. The realisation of this type of task involves an increase of premotor cortex [19] and cerebellar neural activities [6]. More recent positron tomographic studies on the effects of a capsular stroke showed moreover that the same structures are also involved in motor recovery [3, 27, 29].

Thus, the motor recovery and the effort sensation might result from the same neurophysiological mechanisms, and we report here a long-term study of these parameters in a case of pure motor hemiplegia which was followed regularly over the course of 4 months.

Case report

C.P., a right-handed man was a 39-year-old jurist who developed a sudden complete hemiplegia on 11 February 1991. Initially, there was no loss of consciousness, no headache or vomiting and no stiffness of the neck. The patient was unable to move his right arm or leg. There were no sensory symptoms. Speech was mildly dysarthric and there was a right central facial paresis, but no deviation. On neurological examination, muscle tone was reduced in the upper and the lower limb on the right and the Babinski response was present on the right. Sensation of touch, pain, temperature and joint position was unimpaired on the right side. Examination of his visual field, eye movements and other systems showed no abnormalities.

At the beginning, when the patient formed the intention of moving his limb, he felt no effort. Over a period of 3 weeks, motor power gradually improved. Movements at the elbow and shoulder were weak. Flexion of the fingers was possible without resistance while finger extension, especially for the thumb, were totally impaired. As soon as the smallest movement became possible, the patient spontaneously complained of a striking sensation of effort in his upper limb when he performed a movement.

Apart from severe high blood pressure, no other contributing factor to this patient's hemiplegia were found. Investigation of heart (including electrocardiography), blood and urine were normal. Bilateral carotid and vertebral angiography showed discrete abnormalities consistent with multiple atherosclerosis plaques. A cerebral CT revealed a round area of infarction in the posterior limb of internal capsule (Fig. 1). This case thus showed many of the clinical and pathological features in common with a series of patients with pure motor hemiplegia described by Fischer and Curry [9].

Two months after the stroke, the patient was able to walk with a walking-stick. Four months later, he became able to handle a fork when eating and a pen when signing.

Methods

Experimental procedures

The evolution of the patient's sensation of effort was investigated at the arm level. An estimate of the effort sensation for movements performed on the right side was obtained by matching the same effort sensation level with the left side movements. The measurement of the sensation of effort was obtained as follows: First, the patient had to realize a movement without resistance on the paretic side and to concentrate on the felt effort; second, he was asked to perform the same movement on the healthy side against a resistance. The resistance was gradually increased by the investigator until the sensation of effort was reached, using weights of increasing value.

Three movements were studied: (1) shoulder forward flexion up to horizontal with the elbow held fully extended, (2) supined elbow flexion up to horizontal without involvement of shoulder movement, and (3) full hand digital grip. Before the test, the subject was repeatedly instructed that the relevant parameter to match on the healthy side was the sensation of effort felt on the affected side. For each of the three movements tested, the patient had first to execute the movement with the impaired arm, and then with the unimpaired arm. The autoevaluation of effort was based on the lifting movement itself, and not on the holding of the final arm position.

During the experiment, the patient was seated comfortably facing a wall with landmarks corresponding to the endpoints of shoulder and elbow movements. For shoulder and elbow movements, the patient was holding with the supined hand a handle sustaining a hook to which various weights could be attached. The minimal step between two different weights was equal to 250 g. For grip movements, an air dynamometer was used (VIGORIMETRE®) providing pressure values in kPa. The bulb chosen was corresponding to the hand size of the patient. In addition, the observer noted related clinical events occurring during each session.

The tests were performed by the same investigator and under the same conditions, at the same time of the day (9:00 a.m.), before starting the daily motor rehabilitation program. After the sensation of effort reached a normal value (zero), the measurement was continued on the paretic side, for estimating the recovery of motor power in the same way as described above. The same procedure was repeated under identical conditions two or three times a week during a period of 4 months.

Statistical analysis

Time courses of effort sensation and force displayed in Fig. 2 for each joint tested suggests that evolution of these variables is better describable by steps and plateaus, rather
Fig. 1. CT 1 year after onset. Section shows a round hypodensity in the left hemisphere consistent with a lacuna in the posterior limb of the internal capsule, which encroaches upon the lateral thalamus.

than by a smooth trend. To support this view, data were subjected to cluster analyses (K-means clustering method, allowing the specification of the number of clusters). The six variables measured (three effort sensation and three force) were included in the analysis, and the 37 measurement days were taken as cases. The aim of these analyses was to define how many clusters of greatest possible distinction could be defined in the data, and to identify each cluster's members. A problem encountered with cluster analysis on serial data is that it may group together data from non-adjacent measurements. We attempted to bear out this problem by the following method: Starting with ten, clusters analyses were computed with a decreasing number of clusters, until each cluster contained only adjacent measurement days.

An analysis of variance (ANOVA) was then performed in order to evaluate the between-cluster variability against the within-cluster variability, computing the significance test for the hypothesis that the variable means in the clusters are different from each other. Ideally, one would obtain very different means for most of the variables used in the analysis. The magnitude of the F-values is an indication of how well each variable discriminates between clusters.

In addition, Scheffe's post-hoc tests were computed to compare values of clusters one to each other, for all six variables measured. Again, if an efficient clustering was obtained, then most of these post-hoc tests should be significant.

In order to study the possible relationships between effort sensation and force, a multiple regression was computed on these variables. If similar time courses were to be observed for the different variables, this regression analysis should provide significant correlation between most of them. Cluster number was added to this analysis to check the quality of the clustering previously obtained. Again, if the time course of the six measured variables is linked to the above-defined clusters, then one would expect high correlations between cluster number and measured values.

Results

Qualitative observations

Initially, the execution of movements on the paretic side required an important effort of concentration, which was spontaneously reported by the patient. This phenomenon was mostly pronounced for the hand grip movement. The execution of the empty hand grip movement was accompanied by a transient breathlessness. Moreover the patient himself complained of an increase of heartrate during this task. These observations were only noted for the first two sessions [from the first to the third day (D1–D3)]. Syncinesia was observed during the execution of shoulder movement, from D1 to D10. They appeared at the time the reported sensation of effort reached the matching level. They consisted of an incomplete shoulder forward flexion in the paretic side, involving an internal rotation component, consistent with imitation syncinesia. The amplitude of this movement was approximately 60 degrees. Syncinesia was never noticed for the other two movements.

Evolution of sensation of effort and motor power for grip movement

The initial value of matching force with the left hand was 98 kPa. This value corresponded to the maximal motor power of the left hand. Then the effort sensation
rapidly decreased down to zero within 7 days and consistently kept this value up to D100. From D1 to D7, the motor power was reduced and the grasping movement was solely possible without resistance. From D8, the motor power was gradually increasing. This increase was not characterized by a linear progression. Instead two different phases could be described: one phase from D8 to D53, and one phase from D57 to D100. The transition between the two phases seems to occur between D53 and D57 (Fig. 2a).

Evolution of sensation of effort and motor power for elbow movement

The initial matching weight obtained for elbow movement was 19 kg. It remained stable within a ±2.250 kg range from D1 to D18. From D19 to D24, this weight decreased from 19 to 9 kg, and then remained unchanged between 7 and 12 kg from D24 to D52. Again a dramatic decrease from 7.500 to 0 kg was observed between D52 and D56. During the decrease of the sensation of effort (from D1 to D53), no motor power could be measured. The patient was only able to flex the elbow against gravity, but not against resistance. A progressive improvement of the motor power was observed, as soon as the sensation of effort was reduced to zero. This improvement seemed to involve three successive stages: from D57 to D81; from D85 to D101; and from D112 to D122 (Fig. 2b).

Evolution of sensation of effort and motor power for shoulder movement

The matching weight observed for shoulder movement was initially 10 kg. It remained stable between 10 and 11 kg up to D28. Within 2 days, between D28 and D30, the matching weight decreased from 10 to 8 kg. From D30 to D56, this again remained stable between 7.500 and 9 kg. From D56 to D66, a reduction of the matching weight is observed from 8 to 0 kg. As reported for elbow movement, the matching weight value remained fixed to 0 kg up to D100. As for other joints, the motor power could only be tested from the suppression of the sensation of effort, precisely at D67. Starting at D67, a progressive increase of the motor power was observed, comparable with the curve for elbow movement. As previously observed, three main successive stages could be described. Their duration was identical and the curve can be superimposed on the previous one (Fig. 2c).

In the following analyses, values of effort sensation and motor power were expressed as a percentage of their respective maximal value. Thus all values ranged from 0 to 100% (Fig. 2).

Cluster analysis

Cluster analysis was performed in order to decide whether objective periods could be distinguished within the course of the evolution. Analyses were performed for 10, 9 and 8 clusters. For 10 and 9 clusters, the
clusters provided did not include only consecutive measurement days (e.g. creating an artificial group with measurement days 28, 31, 33 as cluster members). For 8 clusters, the analysis provided groups that included only consecutive measurement days, thus respecting the serial nature of the data. Table 1 displays the boundaries of each cluster, defining 8 periods of time within the whole data set. The number of measurement days included in each cluster ranged from 2 to 8. Figure 3 shows that the longest period can be considered as plateaus (e.g. clusters 2, 4 and 7), whereas the shortest one can be considered as transitions between plateaus (e.g. clusters 3 and 5). Mean values of each variable obtained within each period are also shown in Table 1. These values help to understand how the clusters were defined. For example, cluster 5 is the only period during which (1) the sensation of effort felt at the elbow level was already null and (2) the motor power measured at the shoulder level was still null. Clusters 2, 3 and 4 on the one hand, and clusters 6, 7 and 8 on the other hand, are distinguishable by the difference in the mean value of three variables.

**Analysis of variance**

The ANOVA results provided on Table 1 demonstrate that all six variables participated in the cluster definition: The high F-values obtained for each variable demonstrate that means of all the variables are significantly different between clusters.

*Post-hoc* tests were processed for each variable to assess the significance of the one-by-one differences between clusters. Twenty-eight tests were computed for each variable. For the effort sensation at the grip level, cluster 1 was significantly different from any other cluster ($P<0.0001$). For effort sensation at the elbow level, the only no-significant differences were observed among clusters 5–8, between clusters 1 and 2 and between clusters 3 and 4. All of the 20 other Sheffe’s tests were highly significant ($P<0.0001$). For the effort sensation at the shoulder level, non significant tests were observed between clusters 1 and 3 and between clusters 6 and 8. All of the 22 other Sheffe’s tests were significant at $P<0.005$ (20 of them at $P<0.0001$). For the grip motor power, significant differences were obtained between cluster 1 and every other cluster ($P<0.05$ in one case; $P<0.0001$ in all others), between cluster 5 and clusters 2 and 3 ($P<0.03$), between cluster 7 and clusters 2–4 ($P<0.0003$), and between cluster 8 and clusters 2, 3, 4 and 6 ($P<0.02$). For the elbow motor power, clusters 1–4 were significantly different from clusters 5 to 8 ($P<0.02$). In addition, cluster 8 was different from all others ($P<0.0001$). For the shoulder motor power, clusters 6–8 were significantly from one each other, and from all other clusters ($P<0.0001$).

Taken all together, these *post-hoc* results show the strength of the boundaries between clusters. They may be summarized by emphasizing the differences between the three main plateaus observed (clusters 2, 4 and 7). The transition between cluster 1 and 2 is dependent only on effort and power at the grip level. Then transition between cluster 2 and cluster 4 is marked by significant differences in the effort sensation felt at the elbow and shoulder level. The transition between cluster 4 and 7 corresponds to significant changes in all variables except effort sensation at the grip level. The upper boundary of cluster 7 also corresponds to significant changes in elbow and shoulder power. In addition, transition between cluster 4 and 5 reflects significant changes in three variables, and transition between cluster 5 and 6 reflects significant changes in two variables. These results strongly argue for the existence of critical periods corresponding to a simultaneous improvement in effort sensation and in motor power at one or several joint levels.

Table 1. Mean values of the six variables explored computed within each period defined by the cluster analysis. First and last measurement days included in each cluster are indicated ($n$ = number of measures). ANOVA results demonstrates that these means were significantly different across periods.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cluster 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort Grip</td>
<td>93.40</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Effort Elbow</td>
<td>91.47</td>
<td>87.04</td>
<td>48.04</td>
<td>36.63</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Effort Shoulder</td>
<td>95.45</td>
<td>96.75</td>
<td>93.18</td>
<td>73.86</td>
<td>56.06</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Power Grip</td>
<td>0.00</td>
<td>42.55</td>
<td>31.91</td>
<td>48.40</td>
<td>68.09</td>
<td>58.16</td>
<td>76.16</td>
<td>86.70</td>
</tr>
<tr>
<td>Power Elbow</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>24.00</td>
<td>30.67</td>
<td>38.29</td>
<td>78.80</td>
</tr>
<tr>
<td>Power Shoulder</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>25.64</td>
<td>52.75</td>
<td>86.15</td>
<td>284.2</td>
</tr>
</tbody>
</table>

$F$ (7, 29) $P$  
634.7 0.000001
257.6 0.000001
431.7 0.000001
86.70 0.000001
78.80 0.000001
104.8 0.000001
284.2 0.000001
Multiple regression

In order to further demonstrate that effort sensation and motor power measured at several joints progress in a parallel way, a multiple regression was computed between the six variables. As can be seen on Table 2, 18 out of the 21 correlations computed were significant against zero. These three non significant correlations were obtained with the effort sensation measured at the grip level, probably because no variation of this variable was observed after the fourth measurement day. The highest correlations were obtained between cluster number and the other variables. This result further suggests cluster definition was significantly correlated with all variables. As a summary, Fig. 4 shows the relationship between the mean effort sensation, the mean motor power (averaged across joints) and cluster number. The multiple linear regression computed between these variables reached high statistical significance \[ F(2, 34) = 686.28; P < 0.0001 \]. The three partial regressions obtained between these variables were also highly significant \[ F(1, 35) > 82.0; P < 0.0001 \]. This additional result further demonstrates the strong relationship between effort, power and cluster number.

Discussion

There are several aspects of this work to be discussed. First, it was observed that motor recovery measured by power at a given joint level was initiated only after the effort sensation—without resistance—of this joint had fully recovered (Fig. 2). Second, cluster analysis demonstrated that effort sensation and motor power followed a plateau and step evolution in time (Figs 2 and 3). Third, post-hoc analysis suggested that evolution of the patient was marked by critical periods during which both sensation of effort and motor power measured at the three joint levels rapidly improved (Table 1 and Fig. 3). This was confirmed by regression analyses showing that most of the variables measured were highly correlated (Table 2) and that a strong correlation was observed between the mean effort sensation, the mean motor power and periods of evolution (Fig. 4). The following discussion will address these three main points.

The sensation of effort in C.P. appears only with the earliest signs of motor recovery. In the beginning, the
The sensation of effort measured at the grip level is significantly correlated with grip power and effort sensation at the elbow. All other variables are significantly correlated from each other. Note that cluster number is highly correlated to all variables measured.

Table 2. Correlation matrix of the six variables explored. Positive values indicate similar trends over time and negative values indicate trends in opposite directions. The sensation of effort measured at the grip level is significantly correlated with grip power and effort sensation at the elbow. All other variables are significantly correlated from each other. Note that cluster number is highly correlated to all variables measured.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effort Grip</th>
<th>Effort Elbow</th>
<th>Effort Shoulder</th>
<th>Power Grip</th>
<th>Power Elbow</th>
<th>Power Shoulder</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort</td>
<td>1.00</td>
<td>0.46*</td>
<td>0.31</td>
<td>-0.67**</td>
<td>-0.23</td>
<td>-0.21</td>
<td>-0.47*</td>
</tr>
<tr>
<td>Grip</td>
<td>0.46*</td>
<td>1.00</td>
<td>0.87**</td>
<td>-0.79**</td>
<td>-0.72**</td>
<td>-0.65**</td>
<td>-0.93**</td>
</tr>
<tr>
<td>Effort</td>
<td>0.31</td>
<td>0.87**</td>
<td>1.00</td>
<td>-0.77**</td>
<td>-0.84**</td>
<td>-0.86**</td>
<td>-0.95**</td>
</tr>
<tr>
<td>Elbow</td>
<td>-0.67**</td>
<td>-0.79**</td>
<td>-0.77**</td>
<td>1.00</td>
<td>0.73**</td>
<td>0.71**</td>
<td>0.87**</td>
</tr>
<tr>
<td>Shoulder</td>
<td>-0.23</td>
<td>-0.72**</td>
<td>-0.84**</td>
<td>0.73**</td>
<td>1.00</td>
<td>0.94**</td>
<td>0.87**</td>
</tr>
<tr>
<td>Power</td>
<td>-0.21</td>
<td>-0.65**</td>
<td>-0.86**</td>
<td>0.71**</td>
<td>0.94**</td>
<td>1.00</td>
<td>0.86**</td>
</tr>
<tr>
<td>Elbow</td>
<td>-0.47*</td>
<td>-0.93**</td>
<td>-0.95**</td>
<td>0.87**</td>
<td>0.87**</td>
<td>0.86**</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Indicates P<0.01; **indicates P<0.001

A stage of exaggerated effort sensation, during which the motor power remains weak and stable; (iii) a final stage during which motor power improves. The curves of mean effort sensation and mean motor power following alternating steps and plateaus. In fact, an optimum partition of all measurement days was found for 8 periods of time by the cluster analysis. These 8 periods of time correspond to different evolutions of the effort sensation and motor power measured on each joint (Fig. 2). As can be seen in Fig. 3, it is interesting to notice that steps occurred during short critical periods for the two types of variables.

Comparative recovery curves, proceeding by steps, have been reported following experimental lesions of the nervous central systems: area 4 in macaca monkey [16], after hemilabyrinthectomy in cats [5]. In stroke populations, functional motor recovery curves also correspond to a non-linear process [4, 17, 22, 25, 26, 28]. These steps and plateaus could express a staged process, reflecting the complexity of neurophysiological mechanisms involved in the recovery [20].

In C.P., these steps seem to be consistent with crucial periods in the restoration process. They might be analysed as the result of an improvement of neural traffic in the internal capsule, responsible for a reduction of the signal of motor command [11]. The suppression of a transient conduction block analogous to neuropaxia in the peripheral nervous system cannot explain this improvement of the neural traffic, because a lacuna persists in the posterior limb of the internal capsule. This improvement cannot be found in a potential cortical diaschisis, because ipsilateral cortical hypometabolism is absent from patient with lesions limited to the posterior limb of the internal capsule [27]. Rather, this improvement by step might correspond to a restoration of nervous conduction in corticofugal fibres [12]. A reorganization of new connections might also be discussed; for example, in stroke patients with an
isolated lacuna in the internal capsule, Fries et al. [10] have shown that a suprathreshold stimulation of the affected hemisphere elicited through bilateral motor responses in the thenar muscles, consistent with polysynaptic corticoreticulospinal connections.

What does the sensation of effort in C.P. mean? It might be interpreted as a cognitive manifestation associated with the recovery of motor power. The sensation of effort could be considered as one of the several aspects of the motor recovery. According to this interpretation, the sense of effort and the motor power could depend on the same neurophysiological mechanisms, involved in the motor recovery. At least part of the neuronal circuitry involved in the motor command seems to be implicated in the generation of effort sensation. In normal subjects, the sensation of effort which is observed during mental execution of movement led Jeannerod [21] to propose that the sensation of effort might be a subjective correlate which can become perceptible to the actor independent of overt movement execution and can be monitored experimentally. Thus the sensation of effort and force might result from the same structures involved in the force and effort representation [21].

The sensation of effort does not seem to result directly from the pyramidal tract because transcranial electrical stimulation does not produce a sensation of effort [12]. In our patient, it may be hypothesized that the central nervous system recruits more motor cortical columns involved in the motor programming and execution, due to the important reduction of neural traffic in the internal capsule. During the early recovery, the neuronal recruitment would not be sufficient to improve the force, but still could generate a sensation of effort. Sensation of effort could thus correspond to an exaggerated activation of the motor representations involved in motor programming. A signature of this exaggerated activation could also be found in the syncinesia observed during the early stages, which suggests a bilateral activation of motor areas. A high level of activation would remain until the permeability of the internal capsule improves. As and when the neural traffic increases, the decrease in activation would consecutively induce a reduction of the intensity of the effort sensation. From the time, the neural conduction can give arise to a satisfactory motor execution, normal motor representations are implemented and the exaggerated effort sensation disappears.

References


Acknowledgements—The authors wish to thank Prof. Marc Jeanneerod from Vision et Motricité INSERM U94 for his comments on an earlier version of this manuscript and Amanda Bishoff from University of Southern California and Suzanne Gay for her help with the English version. A preliminary report about this work was presented at the International Congress on Stroke Rehabilitation (Berlin, 1993).


