The Rehabilitation of Limb Apraxia: A Study in Left-Brain–Damaged Patients

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Objective: To assess the effectiveness of a rehabilitative training program for patients with limb apraxia.

Design: Randomized, controlled trial.

Setting: Neurologic rehabilitation unit of a university hospital.

Patients: Thirteen patients with acquired brain injury and limb apraxia (lasting more than 2 months) as a result of lesions involving the left cerebral hemisphere. Patients were assigned to a study group or to a control group following a randomization scheme. The study group underwent an experimental training for limb apraxia. The control group received conventional treatment for apraxia.

Intervention: A behavioral training program consisting of gesture-production exercises. The rehabilitative program was made up of 3 sections dedicated to the treatment of gestures with or without symbolic value and related or nonrelated to the use of objects. Thirty-five experimental sessions, each lasting 50 minutes, were given.

Main Outcome Measures: Neuropsychologic tests for assessment of apraxia, verbal comprehension, “general intelligence,” oral apraxia, constructional apraxia, and 3 tests concerning limb praxic function (ideational apraxia, ideomotor apraxia, gesture recognition). Scores related to each test were used to measure the outcome. Video recordings of ideational and ideomotor apraxia tests allowed us to register type and number of praxic errors. All outcome measures, except the apraxia test, were recorded before and after the experimental (or control) treatment time interval.

Results: The patients in the study group achieved a significant improvement of performance in both ideational (p = .039) and ideomotor (p = .043) apraxia tests. They also showed a significant reduction of errors in ideational (p = .001) and ideomotor (p < .001) apraxia tests. A trend toward improvement was found in the gesture comprehension test (p = .058), while other outcome measures did not show any significant amelioration. Control patients did not show any significant change in performance.

Conclusions: The results show the possible effectiveness of a specific training program for the treatment of limb apraxia.

Key Words: Apraxia; Rehabilitation; Stroke.

Limb apraxia (LA) is a common sequela of left-brain damage that consists of a deficit in performing gestures to verbal command or to imitation. This disturbance cannot be explained by intellectual deterioration, poor comprehension, uncooperativeness, or by a deficit of elemental motor or sensory system. LA typically affects both the ipsilesional and the contralesional limbs. Patients suffering from LA are particularly impaired when asked to demonstrate how to use an object or how to carry out actions involving a single or a series of components of movements. Thus, the performance is characterized by a series of errors leading to an incomplete, distorted, and/or ineffective gesture. Based on the analysis of apraxic behavior, 2 forms of LA can be distinguished: “ideational” (IA) and “ideomotor” (IMA) apraxia. In the case of IA, the pattern of gestural errors shows that patients are unable to plan a given action (ie, they try to pour the water from the bottle into the glass, without having previously taken off the cap). Moreover, their gestures are often conceptually inappropriate to the context (ie, patients stir the bottle opener inside the glass). As a result, some authors consider IA as a disturbance of conceptual knowledge regarding the use of tools and objects. On the other hand, because patients with IA can show a failure in retrieving semantic information related to the use of objects, this syndrome has also been thought of as a semantic memory disorder. Unlike IA, IMA is characterized by a global preservation of action-planning ability, in spite of a defective execution of the gestural motor program. Therefore, gestural errors in IMA are mainly spatial distortions, gesture configuration (eg, orientation), poor joint coordination, and timing errors (eg, abnormal slowness). According to recent studies, patients with IMA show an impairment of gesture learning, which is considered to be the consequence of a “motor memory” disorder. Epidemiology studies report that IA is present in 28% of left- and in 13% of right-brain–damaged patients, in the acute stage of stroke. The incidence of IMA is 57% of left- and 34% of right-brain–damaged patients. LA tends to ameliorate in the course of the first months after stroke onset. Nevertheless, Basso and coworkers reported that IMA persisted to some extent in 45% of patients of any severity 1 year after stroke onset. Although IA and IMA can occur separately, both types of apraxia are frequently associated with one another.

A puzzling aspect of apraxic behavior is that gestural abilities change dramatically under different contextual situations. Thus, the same patient who is unable to make the sign of the cross during formal assessment of apraxia may be able to produce the correct gesture when he/she is entering a church (the so-called “automatic-voluntary” dissociation). This shows that contextual cues play a critical role in the pathogenesis of LA, and that apraxia tends to decrease during daily-life conditions. On the basis of this observation, many clinicians believe that apraxia has little negative impact on patients’ lives, and
consequently that there is no need to manage and treat LA. However, recent studies have shown that the so-called “automatic-voluntary” dissociation in LA is not an “all or none” phenomenon, and that apraxic disability could also emerge in many natural situations. To investigate the impact of LA phenomenon, and that apraxic disability could also emerge in addition to appropriate eating utensils, tool foils (toothbrush, comb, and pencil) were also placed on the lunch tray. The result of the study indicated that the left-brain–damaged group was less organized in their meal performance, used fewer tools, and produced fewer tool actions than the control group. In addition, there was a significant positive correlation between the degree of apraxia severity and the number of action errors.

The disabling effects of LA are also underlined in a study by Sundet and coworkers, who evaluated the dependency on caregiver assistance in activities of daily living of patients with left- or right-hemisphere strokes at 6 months’ postonset. The results showed that measures of apraxia are highly correlated with the level of dependency estimated by caregivers, and that patients with LA required more assistance with tasks of daily life than patients with other neuropsychologic deficits. These data are in keeping with Saeki and colleagues, who found that apraxia delays return to work in brain-damaged patients. The negative effects of LA are well known by physical therapists who try to rehabilitate motor disability in stroke patients. Indeed, neuromotor rehabilitation programs imply that patients are involved in a continuous action-planning activity. Therefore, in patients with apraxia, physical therapists are compelled to change the typical rehabilitative strategy in which patients are requested to execute purposeful movements on command. Indeed, in apraxic patients, motor goals should be achieved without (or with only a marginal) involvement of the patient’s will. This can be done, for example, by passively guiding the patient’s motor activity. Though effective, this approach to stroke motor disability is very laborious, leading in most cases to a significant prolongation of time of treatment.

A further disability that is reported to affect apraxic patients is a reduction of the spontaneous use of communicative gestures.

This is even more important if we consider that approximately 80% of patients with LA are also aphasic, and that gestural communication is sometimes the only residual way of social interaction for many aphasic patients.

Although previous observations show that effective management and treatment of LA could have a potentially great impact in clinical practice, literature on rehabilitation of LA is very scant, and only a few single-case rehabilitative studies are reported (see also Maher and Ochipa for a review).

The aim of the present study was to assess the effectiveness of an experimental program for the treatment of LA. Thirteen patients were allocated to a study group or to a control group. The study group underwent a rehabilitative training consisting of gesture-production exercises, while the control group received conventional treatment for aphasia. To our knowledge, this is the first controlled study on the rehabilitation of LA.

### METHODS

#### Patients

Ten men and 3 women, with radiologic (computed tomography) scan and clinical evidence of left-sided unilateral vascular lesions, participated in the study. Subjects were selected from a series of left-brain–damaged, aphasic patients who had undergone language rehabilitation at the Neurorehabilitation Unit of the Policlinico Borgo-Roma (Verona, Italy). The main criteria for inclusion in the study were the presence of LA (IA and/or IMA) and a length of illness of at least 2 months. Twelve patients suffered from ischemic stroke, and 1 suffered from hemorrhagic stroke. The Briggs and Nebes’ laterality inventory showed that all patients were strongly right-handed (table 1). All patients had no history of cerebrovascular attacks or

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Abbreviations: F, frontal; P, parietal; T, temporal; O, occipital; thal, thalamus; b.g., basal ganglia; ins, insula; cort, cortical; subcort, subcortical.
psychiatric disorders. Motor and somatosensory impairment and visual field defects were assessed according to a standard procedure used by Bisiach and colleagues, in which severity could vary along a 4-point scale (0 indicating minimal or no deficits, and 3 indicating severe deficits). Motor and somatosensory impairment was examined for upper and lower contralateral sionalims. Visual-field defect was examined for upper and lower contralateral visual-field quadrants. A degree of neurologic severity was obtained by summing all subscores of the Bisiach test (range, 0-18). Aphasia diagnosis was performed according to the Language Examination Test in use at the Neuropsychology Center, University of Milan. All patients were informed of the experimental nature of the study and gave their consent for participation. The study was carried out following the guidelines of the Declaration of Helsinki. The protocol was approved by the local ethics committee.

The first 10 patients were assigned to the study group or the control group by following a simple randomization scheme. This procedure brought about a different number of patients in each group. To avoid a further imbalance, we adopted a restricted randomization scheme by assigning the last 3 patients to the control group. The study group underwent an experimental rehabilitative training for limb apraxia. The control group received conventional treatment for aphasia lasting the same number of hours as the experimental treatment. As a control procedure, we preferred treatment of aphasia instead of occupational or physical therapy programs, based on the assumption that both apraxia and aphasia are related more to higher-order deficits than low-level sensory-motor variables.

The study was carried out in an outpatient regime. Demographic and clinical details of the 2 groups of patients are shown in table 1.

Ten separated independent-sample Mann-Whitney tests (carried out by SPSS for Windows, version 7.0) showed that age, education, handedness, neurologic severity, length of illness, intelligence, verbal comprehension, IA, IMA, and gesture comprehension were not different in the control-group and study-group patients (age, U = 12.5, p = .22; education, U = 14.0, p = .28; handedness, U = 17.0, p = .43; neurologic severity, U = 20.0, p = .88; length of illness, U = 12.5, p = .22; intelligence, U = 13.0, p = .25; verbal comprehension, U = 20.5, p = .94; IA, U = 18.5, p = .71; IMA, U = 17.0, p = .56; gesture comprehension, U = 17.0, p = .87) (see below for details on neuropsychologic assessment).

Test Procedure

Before and after the treatment, all patients underwent a battery of neuropsychologic tests including the following: a verbal comprehension test (Token Test by De Renzi) in which patients are asked to reproduce a wide variety of intransitive gestures (ie, not requiring use of objects). No gestures requiring use of objects (transitive gestures) were used in this test. Gestures could be symbolic (eg, sign of O.K.) or nonsymbolic (hand under the chin). If an item was not correctly reproduced on the first demonstration, a second demonstration was given. In case of a repeated failure, a third demonstration was given. The patient was credited 3, 2, or 1 points if he or she performed flawlessly on the first, second, or third demonstration; if all demonstrations were unsatisfactory, the patient was credited 0 points. The test included 24 items (score, 0-72). According to Faglioni, the diagnosis of IMA is reliable for scores under 53 points. The performance of each patient during the IA and IMA tests was video-recorded. The film sequences were checked in separate sessions by 3 speech pathologists who were not aware of the aim of the study. These assessors were requested to analyze the pattern of praxic errors made by the patients. Different categories of praxic errors were recorded in the IA and IMA tests. In the IA test, targeted errors were as follows: perplexity, awkwardness, omission, localization error, inadequate utilization, sequence error, substitution. Praxic errors recorded in the IMA test were: omission, perseveration, perseverative intrusion, wrong effector position, inappropriate sequence, “conduite d’approche” (repeated gestural adjustments to achieve the target gesture), substitution, unrecognizable gesture (see De Renzi and Lucchelli, and Miller for description of errors). Every error was agreed on, and then counted, by the assessors.

Recognition of gestures was tested both for transitive or intransitive-symbolic gestures by means of an original ad-hoc-developed test. As for transitive gestures, the patient was given 3 pictures showing an action (ie, playing guitar) performed respectively with the adequate object (ie, guitar), with a semantically related but inappropriate object (ie, flute), or with a semantically unrelated and inappropriate object (ie, broom) (fig 1). Patients were required to indicate the picture in which the correct transitive gesture was reproduced. As for intransitive-symbolic gestures, the patient was given 3 pictures showing different symbolic gestures, 1 of which (ie, action of praying with clasped hands) was related to a context represented in another picture (ie, the statue of Saint Anthony). The remaining 2 pictures showed gestures with (ie, action of sleeping with clasped hands behind the head) or without (ie, Communist fist) postural affinities with the correct gesture (fig 2). The patient was requested to indicate the picture showing the gesture related to the context. The test included 5 transitive and 5 intransitive gesture-recognition trials. One point was given for each correct response (score, 0-10).

Training Procedure

The experimental treatment was made up of 3 sections, respectively devoted to transitive, intransitive-symbolic, and intransitive-nonsymbolic gestures.

Transitive gesture training. This section was subdivided into the phases A, B, and C. In phase A, the patient was required to show the use of common tools (ie, a spoon). In phase B, the patient was shown a picture illustrating a transitive gesture (ie, using a spoon), and then required to produce the corresponding gestural pantomime. In phase C, the patient was presented a picture showing a common tool (ie, a spoon), and then required to pantomime the use of that object. Each phase contained 20 items. When the patient was able to correctly perform at least 17
of 20 items, a phase was concluded and the following one started.

**Intransitive-symbolic gesture training.** Like the previous section, this section was subdivided into phases A, B, and C, depending on the amount of contextual cues used in the different conditions. In phase A, the patient was shown 2 pictures, one of which illustrated a given context (ie, a man eating a sandwich), and the other showing a symbolic gesture related to that context (ie, the gesture of eating). After the presentation, the patient was asked to reproduce the symbolic gesture shown in the picture. In phase B, the task was to produce the correct gesture (ie, the gesture of eating) after the presentation of the context picture alone (ie, a man eating a sandwich). In phase C, the task was to produce the correct gesture (ie, gesture of eating) following the presentation of a picture showing a new, though similar to the previous one, contextual situation (ie, a man eating canned food with a fork). Each phase consisted of 20 items. The criterion for passing from one phase to another was the same as for the transitive gesture section.

**Intransitive-nonsymbolic gesture training.** The patient was asked to imitate meaningless intransitive gestures previously shown by the examiner. Twelve gestures, involving 6 proximal and 6 distal joints, were delivered. Half of them were static, and the others were dynamic gestures. If the patient was not able to perform a gesture properly, the examiner helped him by means of verbal, or any other possible kind of, facilitation (eg, showing the correct gesture, passive positioning of the hand, passive execution of the complete gesture, etc). For each of the required gestures, the examiner recorded whether the task was carried out with no facilitation, with only verbal or with other additional facilitations. All gestures of the experimental training were different from those included in the IA and IMA tests. Each training session lasted approximately 50 minutes and took place 3 times per week. The order in which training sections and phases were delivered reflects that described in Methods section. Apraxia treatment stopped after the completion of all training sections was reached, or after a maximum of 35 treatment sessions.

**RESULTS**

**Neuropsychologic tests**

Statistical analysis was carried out by using the statistical package SPSS for Windows, version 7.0. Wilcoxon signed ranks tests on pretreatment and posttreatment scores in the different tests were carried out in each group of patients.

In the study group, no significant variation of performance on Token, Raven, Oral apraxia, and Constructive apraxia tests was observed (table 2). On the contrary, a significant improvement of performance was found in both IA ($Z = -2.06, p = .039$) and IMA ($Z = -2.02, p = .043$) tests. Pre- and posttreatment performance in the IA and IMA tests for each patient is shown in table 3.

Overall, praxic errors recorded in the course of the IA test decreased significantly after the rehabilitative training ($Z = -3.23, p = .001$). Analysis of errors for each category of errors showed a significant improvement in awkwardness ($Z = -2.00, p = .046$) and omission ($Z = -2.07, p = .038$) errors. A globally significant reduction of praxic errors was also
Fig 2. Gesture-recognition test. Three symbolic gestures and the targeted context. (A) Adequate gesture. (B) Semantically related but inadequate gesture. (C) Semantically unrelated and inadequate gesture. (D) Context.
found in the IMA test ($Z = -4.58$, $p < .001$). This reduction was statistically significant for unrecognizable gestures ($Z = -2.20$, $p = .027$), intrusion ($Z = -2.26$, $p = .024$), and position ($Z = -2.02$, $p = .043$) errors; a marginal significance was observed for perseveration errors ($Z = -1.84$, $p = .066$).

Figures 3 and 4 show mean praxic errors of the study group in IA and IMA tests, respectively. Finally, a marginally significant improvement of performance ($Z = -1.89$, $p = .058$) was found in the gesture-comprehension test (table 3).

The performance of the control group did not differ before and after the conventional aphasia treatment in any of the neuropsychologic tests (tables 2 and 3).

In the same vein, the number of praxic errors of the control group recorded in the course of the IA and IMA tests did not change significantly. Mean praxic errors in the IA and IMA tests are shown in figures 5 and 6, respectively.

### Behavior During Apraxia Treatment

Patients 1 and 3 were able to complete the training in 34 and 35 treatment sessions, respectively. Gesture learning was slower in the other patients, who were not able to complete the training program within the limit of 35 sessions. In particular, patient 5 stopped treatment at phase C of the symbolic gesture section, patients 2 and 6 at phase B of symbolic gesture section, and
patient 4 at phase A of symbolic gesture section. Figures 7 and 8 show the performance of patients 1 and 2 over the entire period of treatment for apraxia. One can see that within each treatment phase, both patients tend to progressively improve their gestural performance. This improvement parallels a reduction in the patients’ need for verbal, or other types of, facilitation. A similar figure was also observed in the other patients in the study group.

**DISCUSSION**

The present study shows that, following an experimental treatment, patients in the study group achieved a significant improvement of their ability to perform transitive and intransitive gestures. On the contrary, those in the control group did not show any statistically significant variation in any outcome measure. It is relevant that the 2 groups received an equal number of hours of “activity” during which the study group was specifically treated for LA and the control group received conventional treatment for aphasia. This rules out the possibility that the improvement observed in the study group was due to generic occupational factors. The different pattern of behavioral changes in the 2 groups cannot be accounted for by any demographic or clinical factor, because these variables were well balanced. These differential changes could not be ascribed to spontaneous recovery, because all patients from the study group were undoubtedly in a chronic stage of illness (more than 5 months from stroke onset).

On the other hand, 3 control patients (patients 7, 9, and 12) were tested 2 months after stroke onset. Thus, if spontaneous recovery was crucial for these changes, it should have influenced the control group more than the study group. Furthermore, at variance from the other controls, patients 7, 9, and 12 showed a trend toward improvement in all outcome measures. While in the patients in the study group the pattern of amelioration mainly involved markers of limb apraxia, in the above 3 control patients, the improvement was observed in several outcome measures. This supports the idea that the amelioration in the study group was related to the behavioral training, while the amelioration found in patients 7, 9, and 12 of the control group was at least in part related to the natural history of their illness. As previously underlined, research concerning LA rehabilitation is very scant, and current guidelines for treatment of LA are not supported by established empirical evidence.

Maher and colleagues studied the effect of apraxia treatment on a 55-year-old woman, with a 22-month history of IMA. Twenty gestures of common tools and household items were chosen for the study (10 gestures were used for treatment and 10 were not part of the treatment). A within-subject ABA withdrawal design was used. Following the definition of a stable baseline, daily therapy sessions, each lasting 1 hour, were initiated. The training period lasted for 2 weeks. The treatment consisted of presenting the patients with multiple cues (tool, object, visual model, and feedback) and asking them to demonstrate the use of a target tool. A probe measure of 10 meaningless-gesture sequences was also taken daily. After the treatment, the patient showed a significant improvement in performance for both treated and untreated gestures. The probe measure remained stable throughout the treatment phase, indicating that the experimental control was maintained.

To clarify which feature of the procedures of the Maher treatment approach was most effective, Ochipa developed a rehabilitative program devoted to the treatment of particular error types (eg, movement errors, external configuration errors; see Roth for details). Two left-hemisphere–damaged patients with chronic IMA were studied following a multiple baseline across-behaviors design. The 2 patients received a total of 44 and 24 treatment sessions, respectively. The results suggested that both patients achieved considerable improvement in praxis performance. The observed effects were treatment-specific insofar as the incidence of a given error type did not significantly diminish until it was targeted in the treatment. Despite
the positive results of this training, a pretraining to posttraining control by means of the Florida Apraxia Battery failed to show a significant improvement in performance. This suggests that the advantage of the treatment did not extend to untrained activities.

A similar result was reported by Cubelli and coworkers, who submitted a chronic global aphasic patient with severe limb apraxia to a gesture communication training (using various pragmatic techniques such as PACE). Although this patient showed an amelioration in gestural communication, he did not show any improvement in LA tests.

Pilgrim and Humphreys reported the case of a left-handed head-injury patient with IMA of the left upper limb who was trained in the use of objects with his left hand. Rehabilitation was carried out following the principles of the “conductive education” procedures in which goal-directed actions are broken down into component parts performed serially and rhythmically verbalized simultaneously. The patient was given a set of objects used in specific rehabilitation exercises (trained objects) and a set of control objects not used in rehabilitation exercises (untrained objects). Results show that the rehabilitation program induced a selective improvement of gestures that required the use of trained objects. More recently, Goldenberg and Hagmann studied a group of 15 left-brain-damaged patients with apraxia, aphasia, and right-sided hemiplegia. All patients showed a remarkable disability in a test evaluating 3 activities of daily living. Patients were admitted to a therapy study lasting 3 weeks: in the first week, they were trained in only 1 of the 3 activities; maximal support, but no therapeutic advice, was given when the patients had to perform the other activities of daily routine. They were given training in the other 2 activities in the second and third weeks, respectively. Results showed a reduction in errors in a given activity exclusively in the week of training. The absence of improvement in nontrained activities indicates that there was no generalization of training effects. In summary, studies on apraxia rehabilitation generally suggest that praxic deficits are
A novel result of the present study is that the patients submitted to the experimental treatment progressively increased their ability to produce a wide range of gestures. The improvement was not restricted to treated items, but it extended to the performance in IA, IMA, and gesture-comprehension tests (see the Limb Praxic Function Evaluation section). These behavioral changes were parallel to a significant reduction in praxic errors recorded during the assessment of IA and IMA. Therefore, at variance from most reports on apraxia rehabilitation, our results show that training effects could also be extended to untreated tasks. This difference can be explained by methodological differences between the present and previous studies. In the study by Ochipa, training tasks were specifically aimed at differences between the present and previous studies. In the tasks. This difference can be explained by methodological variance from most reports on apraxia rehabilitation, our results requested during the assessment of IA and IMA. Therefore, at gestures used in the training phases were different from those requested during the assessment of IA and IMA. Therefore, at variance from most reports on apraxia rehabilitation, our results show that training effects could also be extended to untreated tasks. This difference can be explained by methodological differences between the present and previous studies. In the study by Ochipa, training tasks were specifically aimed at treating dominant error types that patients committed in a pantomime to command test. On the contrary, our rehabilitative approach was devised to treat a wide range of gestures and reduce all types of praxic errors. In this respect, our treatment procedure is more similar to that used in the Maher study, in which results were in fact more consistent with those of the present study.

Methodological differences between our study and Pilgrim's study can also be noticed. First, the number of treatment items differs consistently, our patients being trained for at least 40 gestures versus the 5 included in Pilgrim and Humphreys's training program. Second, our rehabilitative protocol was made up of different types of exercises (concerning transitive-intransitive, meaningful-meaningless gestures), while only transitive gestures were taken into account in the study of Pilgrim and Humphreys. Third, our rehabilitative approach did not follow “conductive education” principles. Last, the assessment procedure used by Pilgrim and Humphreys (transitive gesture to verbal command, to vision and touch, and to vision only) was very different from that used in our study (object utilization, imitation of symbolic and meaningless gestures) (see De Renzi for details). A direct comparison of treatment effects cannot be made with the studies of Cabelli and of Goldberg and Hagmann, because in both these cases, therapeutic intervention was not primarily directed at rehabilitation of apraxia.

Further discussion is required to explain some interesting peculiarities in our training procedure. At variance from other studies, our training was subdivided into 3 sections, respectively devoted to treatment of transitive, symbolic, and meaningless gestures. In the first 2 sections, which cover most of the training, we used changes of contextual cues to teach patients how to produce the same gesture under different contextual situations. This procedure was devised to widen the range of utilization of the acquired gesture ability. In the last section, patients had to repeat some meaningless gestures. This part of the training was included because the ability to produce these gestures is an important requirement for patients who need motor rehabilitation. Indeed, despite the minor relevance of meaningless gestures in daily life, most motor rehabilitation exercises were based on unusual motor sequences that are particularly challenging for apraxic patients.

To conclude, in keeping with previous reports, the present study shows that apraxic patients participating in intensive rehabilitation training improve their gestural performance. Moreover, our experience shows that a training program aimed at ameliorating the widest possible range of gestures could help in the generalization of gestural ability. Although these results are encouraging, at least 3 important questions must be answered: First, is LA rehabilitation also useful in improving gestural performance under daily-life conditions? Second, is LA rehabilitation able to positively influence gestural communication in aphasic patients with apraxia? Third, is LA rehabilitation able to improve patients’ responsiveness during motor neurologic rehabilitation? Answering these questions will be a further crucial step toward a definition of the role of apraxia rehabilitation in reducing disability after stroke.

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References