

Constraint-Induced Therapy of Chronic Aphasia After Stroke

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Abstract—Patients with chronic aphasia were assigned randomly to a group to receive either conventional aphasia therapy or constraint-induced (CI) aphasia therapy, a new therapeutic technique requiring intense practice over a relatively short period of consecutive days. CI aphasia therapy is realized in a communicative therapeutic environment constraining patients to practice systematically speech acts with which they have difficulty. Patients in both groups received the same amount of treatment (30 to 35 hours) as 10 days of massed-practice language exercises for the CI aphasia therapy group (3 hours per day minimum; 10 patients) or over a longer period of ≈ 4 weeks for the conventional therapy group (7 patients). CI aphasia therapy led to significant and pronounced improvements on several standard clinical tests, on self-ratings, and on blinded-observer ratings of the patients' communicative effectiveness in everyday life. Patients who received the control intervention failed to achieve comparable improvements. Data suggest that the language skills of patients with chronic aphasia can be improved in a short period by use of an appropriate massed-practice technique that focuses on the patients' communicative needs. (*Stroke*. 2001;32:1621-1626.)

Key Words: aphasia ■ physical therapy ■ speech therapy ■ treatment outcome

Aphasia arises as a consequence of focal brain damage; cerebrovascular accidents affecting the left hemisphere produce deficits in different aspects of language in approximately 38% of acute cases.¹ A general consensus exists that most of the spontaneous recovery in linguistic function occurs in the first weeks after stroke¹ and is completed by the end of the first year,² although reports exist of improvements occurring as a result of long-term therapy of patients with chronic aphasia.³⁻⁶

Traditional wisdom also had held that recovery of extremity movement usually was not possible >1 year after stroke.⁷ However, a new family of treatments, called "constraint-induced movement therapy" or, more briefly, "CI therapy," has been shown in controlled experiments to produce large improvements in the actual amount of use of more-affected upper and lower extremities.⁸⁻¹⁰ Moreover, the treatment effect not only transfers to the real world setting but shows its largest effect there.¹⁰ The signature technique for treatment of the upper extremity involves constraining use of the less-affected limb for a target of 90% of waking hours (eg, by a resting hand splint and sling ensemble or a protective safety mitt) while intensively training the more-affected extremity for 6 hours each week day. Results indicate that the effective therapeutic factor in CI therapy is the massing or concentration of practice in using the disused extremity for a sustained

period. Constraint may be viewed as simply an adjunctive technique for achievement of this objective.¹⁰

The demonstration that motor behavior is modifiable in patients with chronic stroke opens the possibility that another consequence of stroke, language impairment, may be sufficiently plastic also to be remedied by an appropriate modification of the CI therapy techniques used to enhance rehabilitation of movement of the extremities. When extending the CI approach to language therapy, the important question is how to implement constraints in the therapeutic setting that force the patient to engage in massed practice of those language functions specifically affected by the lesion. In motor therapy, the arm can be constrained by a sling, but how can articulation be induced by constraints? Aphasic patients often use the communication channel that is accessible to them with the least amount of effort; they gesticulate or make drawings instead of using spoken language. Such strategies need to be suppressed in CI therapy in favor of verbal communication. However, even when speaking, patients with aphasia prefer to use the communicative utterances they know they can easily produce. For improving their communicative effectiveness and for avoiding further nonuse of verbal utterances difficult for them, it is imperative to induce them to use words that they normally tend to neglect. However, to prevent repeated failure, its attendant frustration,

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and a return to the patient's everyday loathing to engage in improved linguistic function, it would be advantageous to provide a gradual transition from the communicative behavior that initially is characteristic of a patient to progressively improved linguistic behavior. Making this transition in small steps also is of value so that the required verbal actions are always at the top of the range of patient capability. This type of approach has been termed "shaping," and the small steps are characterized as "successive approximations."¹¹ Finally, and equally importantly, use of a therapeutic setting well tailored to the patients' communicative needs in everyday life is essential to making therapy behaviorally relevant.⁶

One possibility both to tailor therapeutic dialogue to patient needs and to constrain communication in an appropriate manner is offered by modern pragmatic or communicative aphasia therapy.³⁻⁶ To constrain patients' verbal actions in a behaviorally relevant treatment, we used CI aphasia therapy based on therapeutic language games.⁵ Following Wittgenstein,¹² a therapeutic language game is defined by a set of verbal and nonverbal actions in a prearranged environment. Constraints regarding verbal actions and utterances were introduced through (1) the materials used in the game; (2) the rules of the game, as indicated by verbal instruction and shaping; and (3) the reinforcement contingencies, which were individually adjusted by the therapist to the needs of each patient.

In the present study, subjects with chronic aphasia consequent to stroke who previously had participated in extensive conventional speech therapy and had reached an apparent maximum in recovery of language function received CI aphasia therapy for 3 hours each weekday over a 2-week period. A control group of patients received the same number of treatment hours, but in this case, treatment was performed over a longer period (\approx 4 weeks) and followed a well-established technique of conventional aphasia therapy.

Subjects and Methods

A total of 17 patients suffering from aphasia were treated. Patients presented with language impairment due to a single stroke affecting the territory of the left middle cerebral artery. Only patients who had been fully competent monolingual native speakers of German before stroke were included. Patients with severe perceptual or cognitive deficits that did not allow them to participate in aphasia testing or in therapeutic training procedures were excluded. This requirement was assessed by a screening procedure before patients were included in the study. Left-handed patients and patients with additional neurological diagnoses were also excluded from the study. None of the patients had a diagnosis of depression according to *Diagnostic and Statistical Manual of Mental Diseases* (DSM-IV)¹³ criteria. Informed consent was obtained from each subject after he or she received a detailed explanation of the nature of the study. The study was approved by the ethics review board of the University of Konstanz.

Patients were randomly assigned to groups that received either conventional treatment (n=7) or CI aphasia therapy (n=10) by a random process. Each week, patients available in the hospital were screened. If 2 or 3 patients satisfied criteria of the study, a therapy group was initiated after appropriate testing. For each of these cohorts of 2 or 3 subjects, an individual who did not have patient contact previously used a computer-generated random number (0 or 1) to determine the therapy method to be used.

Neurological diagnoses were made by neurologists who were not involved in the therapy study. They were based on standard neuro-

logical assessment and on magnetic resonance imaging or computed tomographic scans. Aphasia diagnoses were made by neurologists and confirmed by speech therapists based on tests, including the Aachen Aphasia Battery.¹⁴ All patients had suffered an ischemic cerebrovascular accident of the left middle cerebral artery with a consequent lesion in perisylvian areas, including, in different patients, parts of the frontal, parietal, and temporal lobes. Before stroke, 3 patients were ambidextrous; the others were right-handed, as confirmed by a standard handedness inventory. The Table shows patient age, sex, education level, handedness, origin of aphasia, number of months after onset of the disease, aphasia syndrome and its severity, language profile at therapy onset, and number of therapy hours given. Patients in the 2 groups did not differ from one another significantly on any of these characteristics, except time after stroke, which was significantly greater in the CI aphasia therapy group (mean[SD], 98.2[74.2]) than in the control group receiving conventional treatment (mean[SD], 24[20.6]). This was an unforeseeable consequence of the random procedure applied. We emphasize that if this difference is important, it would be to the disadvantage of the CI aphasia therapy group. Most of the patients in each group had a moderate language disturbance. The most frequent syndrome was Broca's aphasia; 2 in each group were classified as Wernicke aphasics, and a few patients had other aphasia types (transcortical and amnesic in the CI group and conduction in the conventional group). Patients from both groups were told that they would participate in a therapy study that used modern techniques and, therefore, that extensive testing had to be administered before and after treatment. Care was taken not to inform CI aphasia patients that they were receiving special treatment.

Conventional language therapy was a syndrome-specific standard approach widely used in Germany including components of well-established treatment methods.^{15,16} The therapeutic repertoire ranged from exercises involving naming, repetition, sentence completion, following instructions, and conversations on topics of the patients' own choice. Communicative methods were also included, but this was not the major focus of the treatment. Therapy was administered for 3 to 5 weeks, resulting in a total of 20 to 54 hours (mean, 33.9).

Number of therapy hours per participant in the CI aphasia therapy did not differ from those of patients in the conventional treatment group. Thus, the total amount of therapy was the same for both groups. However, therapy frequency, number of hours per day, differed between groups: patients assigned to the CI group participated in the therapeutic game activity for 10 days, 3 to 4 hours per day (23 to 33 hours of therapy; mean, 31.5). Therapeutic game activity was performed in small groups (2 to 3 patients and the therapist). The game was played with sets of 32 cards containing 1 of 16 pictures on 1 side (2 copies of each card in the set). Barriers in front and on either side of each patient prevented them from seeing each other's hands or cards. The task was to pick 1 card out of the set without showing it to coplayers, explicitly address 1 of the coplayers, and request a card with the depicted object. When addressed by a coplayer, a participant's task was to determine whether he had the card with the requested object on it and, if so, to give it to the coplayer who asked for it. If the participant did not have the requested card (which was frequently the case, because only 2 copies of each card were in the pack), he or she had to deny explicitly the request. All communication had to be performed by use of spoken words or sentences; pointing or gesturing was not permitted. Constraints were introduced to force subjects to use verbal language and to challenge their communicative capacity. These constraints were along 3 dimensions: (1) difficulty of the material, (2) shaping and the rules of the game, and (3) reinforcement contingencies imposed.

Material Constraints

The picture cards showed objects that either had a common name with high word frequency, a less common name, or a name that was phonologically similar to that of another object depicted on 1 of the other game cards (minimal pairs, such as "sock" and "rock"). The cards could include either black-and-white pictures of only 1 object or object pictures of different color or number. By use of the more

Relevant Clinical and Sociodemographic Parameters of Patients in the CI Aphasia Therapy Group and Control Group Receiving Conventional Aphasia Therapy

| Patient No. | Age, y | Sex | Education, y | Handedness | Origin | Months After Onset | Aphasia | | Token Test <i>t</i> | Repetition <i>t</i> | Naming <i>t</i> | Comprehension <i>t</i> | Amount of Treatment, h |
|--|-------------|--------|--------------|--------------|--------|--------------------|---------------|----------|---------------------|---------------------|-----------------|------------------------|------------------------|
| | | | | | | | Syndrome | Severity | | | | | |
| CI aphasia therapy group | | | | | | | | | | | | | |
| 1 | 70 | Male | 13 | Right | CVA | 48 | Wernicke | Severe | 46 | 48 | 54 | 51 | 23 |
| 2 | 72 | Male | 10 | Right | CVA | 72 | Broca | Moderate | 53 | 54 | 56 | 47 | 33 |
| 3 | 55 | Male | 13 | Right | CVA | 38 | Broca | Severe | 46 | 48 | 48 | 54 | 33 |
| 4 | 53 | Male | 10 | Right | CVA | 172 | Amnesic | Mild | 66 | 56 | 69 | 64 | 33 |
| 5 | 39 | Female | 10 | Ambidextrous | CVA | 128 | Broca | Moderate | 59 | 51 | 52 | 53 | 33 |
| 6 | 59 | Male | 13 | Right | CVA | 84 | Broca | Mild | 58 | 55 | 55 | 69 | 33 |
| 7 | 49 | Female | 10 | Right | CVA | 16 | Wernicke | Moderate | 44 | 54 | 49 | 60 | 33 |
| 8 | 44 | Male | 13 | Right | CVA | 233 | Transcortical | Moderate | 49 | 53 | 54 | 58 | 33 |
| 9 | 49 | Female | 10 | Ambidextrous | CVA | 19 | Broca | Moderate | 56 | 60 | 61 | 56 | 28 |
| 10 | 64 | Female | 9 | Right | CVA | 172 | Broca | Severe | 47 | 49 | 51 | 50 | 33 |
| Mean | 55.4 (10.9) | | 11.1 (1.7) | | | 98.2 (74.2) | | | 51.4 (6.9) | 51.9 (4.5) | 54.9 (6.2) | 56.2 (6.7) | 31.5 (3.4) |
| Conventional aphasia treatment control group | | | | | | | | | | | | | |
| 11 | 48 | Male | 13 | Right | CVA | 27 | Conduction | Mild | 57 | 50 | 56 | 70 | 54 |
| 12 | 62 | Male | 9 | Ambidextrous | CVA | 15 | Broca | Mild | 73 | 55 | 59 | 66 | 20 |
| 13 | 42 | Female | 10 | Right | CVA | 11 | Broca | Moderate | 49 | 51 | 49 | 59 | 48 |
| 14 | 57 | Male | 9 | Right | CVA | 58 | Broca | Severe | 49 | 42 | 45 | 48 | 24 |
| 15 | 50 | Male | 9 | Right | CVA | 45 | Broca | Moderate | 49 | 50 | 57 | 55 | 25 |
| 16 | 62 | Male | 13 | Right | CVA | 10 | Wernicke | Moderate | 49 | 62 | 49 | 42 | 33 |
| 17 | 56 | Male | 13 | Right | CVA | 2 | Wernicke | Moderate | 58 | 55 | 52 | 55 | 33 |
| Mean | 53.9 (7.4) | | 10.9 (2.0) | | | 24.0 (20.6) | | | 54.3 (9.5) | 52.1 (6.1) | 52.4 (5.1) | 56.4 (9.7) | 33.9 (12.7) |

complex cards, constraints were systematically introduced for inducement of more advanced verbal communication. For example, the use of a picture that showed a colored object named by minimal pairs (white/black sock/rock) made it necessary to articulate precisely the name of the object and to use a color adjective in addition to the name to achieve success in the game.

Shaping and Rule Constraints

In the initial phase, all approximately relevant utterances could be used; verbal actions subsequently were gradually constrained by explicit rules formulated by the therapist and by shaping and modeling. Constraints included the requirement to use the names of the coplayers or the addition of politeness formulas (eg, “Mrs Jones, please give me. . .; Mr Smith, I would like to have. . .”) and the requirement to use articles and the designation number (eg, “2 muffins”). For advanced patients, syntactic sentence frames were required instead of 1- or 2-word utterances (eg, “Mrs Jones, can I please have 2 muffins?”).

Reinforcement Contingencies

Reinforcement contingencies were adjusted to conform to the performance level each patient was individually capable of. When performance levels varied within a group, a patient with low performance capability was given reinforcement for obeying 1 of the constraints, whereas a more-advanced coplayer received reinforcement only if all constraints were satisfied.

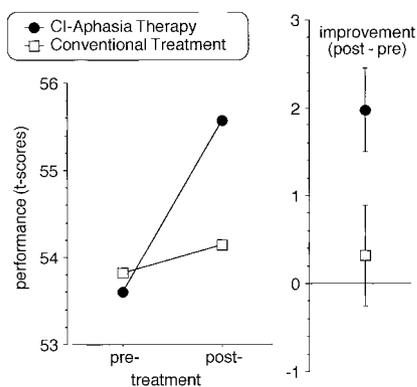
Immediately before and 1 day after therapy, patients underwent testing of language functions. Four subtests of the Aachen Aphasia Battery¹⁴ were administered: the Token Test, and the comprehension, repetition, and naming tests. In the Token Test, the patient has to follow simple to complex commands to touch and handle tokens of different shape, size, and color. The comprehension test requires the patient to point to pictures on advice. In the repetition test, the patient is asked to repeat spoken language sounds, words, compound

words, and sentences. The naming test includes pictures of simple to complex scenes. Their names or descriptions have to be produced. We chose this test battery because it has a high test-retest reliability. Scores have been shown not to increase significantly even if testing is repeated within 3 days.¹⁴ In the standardizing study, scores decreased slightly at second administration in patients with chronic aphasia. Furthermore, the test is characterized by good interrater reliability. Test performance was recorded on a detailed protocol and on audiotape. Clinicians familiar with the test but blinded with regard to patient group membership evaluated these materials. In addition, a questionnaire, the Communicative Activity Log (CAL), was developed to ascertain patient use of verbal language in everyday life (see Appendix). The CAL was modeled on a similar instrument used extensively in CI therapy research, the Motor Activity Log, to obtain information about amount and quality of extremity use in the real-world setting.^{9–12,14–17} This questionnaire includes 2 scales: Amount of Communication and Quality of Communication. The CAL was administered to the patients participating in the study, and, in addition, to therapists in the hospital who were not informed about the specific therapy given to these subjects.

Pretreatment and posttreatment scores on the standard clinical tests were compared between groups by use of *t*-transformed raw values and repeated measures ANOVA. The *t* scale is characterized by a normal distribution and standardized means and SDs (mean[SD], 50[10]). In addition, an estimate of overall language proficiency was obtained by calculating average *t* values over the 4 clinical tests, which were entered into a separate ANOVA. Self-ratings and blinded clinicians’ ratings were compared before and after treatment by use of additional ANOVAs.

Results

Overall scores from the standard aphasia tests revealed a significant interaction of the factors “group” (CI versus



Overall language profile scores calculated as the average of results from 4 clinical tests revealed significant improvement in the CI aphasia therapy group but not in the control group receiving conventional aphasia therapy. Left, Significant interaction. Right, Mean \pm SE of improvements in both groups.

conventional therapy) and "time" (before versus after treatment) ($F[1,15]=5.0$; $P<0.04$). The group that received CI aphasia therapy showed a substantial improvement after the 10-day treatment interval (planned comparison, $F[1,15]=17.3$; $P<0.0008$), whereas the group that received conventional aphasia treatment did not reveal significant overall improvement ($F<1$). The Figure shows significant interaction (left) and mean \pm SE of performance improvements seen in both treated groups (right). Results for the individual tests indicated that improvements in the CI group occurred in 3 of 4 tests used: the Token ($P<0.04$), naming ($P<0.02$), and language comprehension ($P<0.02$) tests, but not the repetition test. In contrast, improvements of the conventional therapy group occurred only on 1 test. We tried to estimate the magnitude of performance increase on the clinical tests by calculating the performance increase on all 4 tests over all subtests on the basis of percentile values. Resulting scores of cumulative change were 17% for the CI aphasia group and 2% for the control group that received conventional aphasia therapy.

Consistent with this result, the CAL revealed that the CI therapy patients' performance in everyday life situations also improved. These patients reported a significant increase of 30% in the amount of communication in everyday life after treatment ($F[1,7]=25.0$, $P<0.001$; average, 30.1 versus 39.2 points). Control patients who participated in conventional aphasia therapy did not show an improvement in this measure ($F<1$).

Improvement in the amount of communication in everyday life seen in the CI group was confirmed by blinded clinicians' ratings available for 7 of 10 patients. This index revealed a quantitative improvement of 10% in communicative activities over the brief 10-day treatment interval ($F[1,6]=10.5$, $P<0.01$; average, 31.2 versus 34.4 points). For each subject, an increase occurred in clinicians' blinded rating scores.

Thus, 6 of 8 calculated measures gave evidence of an improvement in the CI aphasia therapy group, whereas only 1 showed significant improvement in the control group that received conventional aphasia treatment.

Discussion

The present study demonstrates that improvement of language performance in chronic aphasia after stroke can be

achieved by intensive CI aphasia therapy in only a few days. After ~ 32 hours of treatment given over 10 days, substantial improvement occurred in language performance on a standard test for aphasia and an increase of the patients' verbal communication in everyday life. That significant language improvements were obtained over such a short period of time in patients with chronic aphasia (average, 8.3 years after onset) is noteworthy.

Most earlier studies found either no effect of aphasia therapy¹⁸ or significant effects if treatment began within 6 months after onset of the disease and was administered several hours a week for several months.^{19–24} It is generally agreed that a plateau in language function is reached within the first year after stroke.¹ Scattered reports indicate that therapy can produce improvements in linguistic ability after the first year after stroke, but in these studies, therapy was administered for many hours over an extensive period. For example, Elman and Bernstein-Ellis⁴ treated their patients 5 hours per week for 17 weeks and Katz and Wertz²⁵ treated patients for 3 hours per week for 26 weeks. In both cases, total number of therapy hours was more than twice the amount in the present study.

Significant improvement on the naming test in our control group is consistent with prior reports of treatment-induced improvement in patients with chronic aphasia. However, the control patients included in the present study who received conventional aphasia therapy failed to show the marked and global improvements seen in the CI aphasia therapy group, although there was evidence of improvement in the control group as well. We reemphasize that the CI therapy group demonstrated significant improvements on 6 of the 8 language measures used. Most importantly, the measures obtaining information about everyday communication indicated that the amount of language use increased significantly only in the group receiving CI aphasia therapy. No evidence existed for a transfer of the treatment gain to the real-world environment in the conventional treatment group.

The amount of aphasia therapy available to most patients in conventional aphasia therapy is considerably lower than the total 30 to 40 hours within a few weeks administered in the present study. However, some institutions and clinical arrangements do provide this amount of treatment. The contrast here between the results for the CI aphasia and conventional therapy groups, both of whom received the same total amount of therapy, suggests that in those cases, treatment should be given in concentrated massed-practice fashion rather than spread out over an extended period. However, as is the case with any new treatment, the prior question must always be one of clinical efficacy. Results presented here are from a single study into a new therapeutic domain. Replication of these findings in a larger population of patients is important. Furthermore, it is necessary to investigate (1) whether even more intense practice, for example 6 hours a day, can further improve therapy outcome; (2) whether the performance increase reported here can be maintained over longer periods and which amount of therapy is necessary to maintain the enhanced level achieved; (c) whether and in what way neuropsychological deficits (eg, aphasia type) and psychiatric profile (eg, depression) of the patients influence the outcome; and (d) in what way different components of the CI therapy approach contribute to therapy outcome.

The fact that the human brain exhibits so great an amount of plasticity that language can improve late after a stroke and in so short a period of time may have important implications for future therapeutic intervention in aphasia. The present results suggest that the same basic principles relevant to improving extremity function with motor CI therapy may also be relevant to improving language function. These principles include (1) that the use of massed practice for short time intervals is preferred over long-term but less-frequent training (massed-practice principle), (2) that constraints are used that force the patient to perform actions he or she normally avoids (constraint-induction principle), and (3) that the therapy focuses on actions relevant in everyday life (behavioral relevance principle).

These principles, as they apply to enhancing movements of the extremities, appear to be elaborated on the basis of linked but independent underlying mechanisms. First, it has been shown experimentally in monkeys that the abolition of somatic sensation by dorsal rhizotomy from a single forelimb results in permanent nonuse of the affected extremity, because the monkey learns to not use the affected limb in the early postoperative period.^{8,26} The depression in central nervous system motor activity that is present before spontaneous recovery of function has proceeded very far, which makes it impossible for the monkey to succeed at anything it attempts with the affected limb. This failure constitutes punishment for attempted motor activity, which, in turn, suppresses further attempts to use that extremity. Use of just 1 forelimb, while often not efficient, is at least partially successful and, therefore, is rewarded. This punishment (by failure) for attempting to use the affected limb and reward for using just the intact forelimb combines to produce a learned nonuse of the affected extremity. When recovery of function has proceeded far enough to permit use of the affected extremity, the habit of nonuse has become so strong that the potential usefulness of the affected limb is rarely expressed; thus, the learned nonuse becomes permanent. The data suggest that a similar phenomenon occurs after stroke in humans.⁹

The mechanisms responsible for CI aphasia therapy are at present unknown, but they may be related to the way in which motor CI therapy successfully overcomes learned nonuse. For linguistic behavior, learned nonuse is presumed to result from combined punishment (by failure) of complex verbal utterances and reinforcement of alternative communication strategies. CI aphasia therapy is designed to overcome this form of learned nonuse. This does not constitute a contraindication to treatment approaches that use alternative and augmentative communication strategies. These approaches sometimes have been found to enhance verbal communication, in addition to introducing new nonverbal communication.²⁷ Nevertheless, nonuse of verbal communication in favor of pointing and gesturing is a strategy that may develop in patients on the basis of punishment aphasics receive from their partners in everyday life for unsuccessful attempts at verbal communication. We suggest that such learned nonuse may be an important factor in chronic aphasia. From this perspective, the usefulness of complimentary (for example, alternative and augmentative communication) approaches in the context of partner therapy aimed at avoiding such punishment in everyday communication²⁸ appears to be a valuable target of future research.

The second mechanism associated with the effectiveness of motor CI therapy is a use-dependent cortical reorganization induced by the massed-practice nature of the intervention.^{28,29} Evidence has been obtained for the presence of cortical reorganization in patients with chronic aphasia undergoing language rehabilitation.^{30,31} The possible presence and nature of cortical reorganization processes accompanying CI aphasia therapy are presently under investigation.

We reemphasize that the present study cannot answer the question of how much each feature of the CI therapeutic approach to language disorders contributed to the success achieved. Clearly, this new therapeutic approach is based on 3 related principles, each of which could be a sufficient rather than necessary condition for therapeutic success. These different principles include massing of practice, constraints introduced by material difficulty, rules and shaping and reinforcement contingencies, and behavioral and communicative relevance of the therapeutic setting. Clearly, on the basis of the present data, we cannot rule out the possibility that, for example, conventional therapy performed in a massed-practice fashion also could result in pronounced behavioral improvement within a few days. The 3 principles' individual influences should be quantified in future investigations. However, we emphasize that, as outlined above, neuroscientific observations suggest that applying the 3 principles together might be particularly beneficial.

We conclude (1) that massed-practice CI aphasia therapy appears to be efficient for improving language performance of patients with chronic aphasia within a short period of 10 days and (2) that a better outcome was obtained by use of a concentrated CI aphasia therapy regimen instead of the same amount of conventional therapy stretched over a longer period. Future research must determine the specific effect of each of the 3 principles of CI aphasia therapy (massed practice, constraint induction, and behavioral relevance) and ascertain the underlying mechanisms of this new treatment approach.

Appendix

CAL: Amount of Communication

The CAL was administered to obtain information about the patients' communicative behavior in everyday life. As detailed in Methods, CAL versions existed for patient self-evaluation and for evaluation by professional clinicians. Each version of the CAL included items that addressed speech output and language comprehension. Below, items of the CAL presented to blinded clinicians are listed.

1. How frequently would the patient communicate with a relative or good friend?
2. How frequently would the patient communicate when together with a group of friends or relatives?
3. How frequently would the patient communicate with a foreigner?
4. How frequently would the patient communicate when in a group together with several others he or she does not know?
5. How frequently would the patient communicate in an office, store, or public institution (post office, butcher, etc)?
6. How frequently would the patient use the telephone?
7. How frequently would the patient listen to news on the radio or television?
8. How frequently would the patient read the newspaper?
9. How frequently would the patient write down short notes?

10. How frequently would the patient solve simple arithmetic problems?
11. How frequently would the patient communicate when under stress?
12. How frequently would the patient communicate when relaxed and not under stress?
13. How frequently would the patient communicate when he or she is tired?
14. How frequently would the patient make statements or report about facts?
15. How frequently would the patient ask a question?
16. How frequently would the patient answer questions asked by others?
17. How frequently would the patient verbally express criticisms or make complaints?
18. How frequently would the patient verbally respond to criticisms?

All responses had to be made on a 6-point scale in accordance with one of the following: never, almost never, rarely, sometimes, frequently, or very frequently.

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