SPECIAL COMMUNICATION

First Decade of Research on Constrained-Induced Treatment Approaches for Aphasia Rehabilitation

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Approaches for treating poststroke language impairments (aphasia) based on constraint-induced (CI) principles were first introduced in 2001. CI principles as previously applied to upper extremity and locomotor retraining in stroke survivors were derived from basic neuroscience. They comprise forced-use of the affected modality, a gradual rebuilding of targeted functions using a highly intensive treatment protocol, administered in a behaviorally relevant context. CI-based approaches have stimulated considerable neurorehabilitation research interest in the past decade. The original CI aphasia treatment protocol was tailored to improve functional communication in chronic aphasia (ie, 6–12mo after stroke) and more recently, it has been adapted to treat language impairments in acute stroke survivors as well. Moreover, CI therapy applied to aphasia has been used as a model to assess language network plasticity in response to treatment using functional imaging techniques. In the following article, we review the first 10 years of behavioral and functional brain imaging research on CI-based approaches for aphasia rehabilitation.

Key Words: Language disorders; Rehabilitation; Stroke.

POSTSTROKE APHASIA is a devastating language disorder that affects language production and comprehension. Constraint-induced (CI)-based approaches for treating stroke-induced aphasia were first introduced approximately 10 years ago. CI principles known also as use dependent learning principles were derived from basic neuroscience investigations[1] and subsequently applied in human trials investigating treatment of poststroke motor impairments including retraining of locomotion in hemiplegia,[2] partial spinal cord injury,[3] and bimanual usage in hemiplegia.[4]

In 2001, the concept of applying CI-based principles to treat chronic language impairments was introduced, and CI-based approaches have generated considerable interest since that time. The original protocol was tailored to improve functional communication in chronic aphasia (ie, 6–12mo after stroke) and has subsequently been modified and extended by other work-groups to acute stroke and other diagnoses.[5] It has also been used as a model to assess functional brain reorganization in response to treatment using functional imaging techniques.

In the following article, we aim to provide the reader with a short history of CI-based concepts and a comprehensive review and evaluation of the first 10 years of behavioral and functional brain imaging research on CI-based approaches for aphasia rehabilitation.

HISTORY AND DEVELOPMENT OF CI-BASED TREATMENT: WHAT WE LEARNED FROM TREATMENT OF MOTOR IMPAIRMENTS AFTER STROKE

The basic principles of CI-based approaches were derived from animal studies[1] in which monkeys with surgically induced unilateral somatosensory deafferentation would not use the affected extremity spontaneously. Instead, compensatory use of the unaffected extremity occurred. However, it was demonstrated that even years after the deafferentation the monkeys could be trained to make use of the affected limb by restraining the unaffected extremity. In combination with a gradual retraining of motor functions, impairment could be reversed and spontaneous use was reestablished.

Findings from these early studies led to the development of constraint-induced movement therapy (CIMT) to treat patients with chronic stroke and motor impairments.[1] CIMT is centered on 4 overarching principles: the nonuse hypothesis, massed practice, shaping, and behaviorally relevant treatment settings. In the case of motor rehabilitation, it has been suggested that nonuse of an affected (paretic) extremity develops during the first months poststroke when physiologic damage results in depression of function and failure to effectively use the affected extremity (nonuse hypothesis). This nonuse can be overcome by creating situations that induce patients to reuse a paretic limb. In CIMT, this is achieved by constraining the use of the nonaffected extremity by a sling or splint over an

List of Abbreviations

AAT	Aachen Aphasia Test
CAL	Communicative Activity Log
CETI	Communicative Effectiveness Index
CI	constraint-induced
CIMT	constraint-induced movement therapy
fMRI	functional magnetic resonance imaging
MEG	magnetoencephalography
MOAT	model-oriented aphasia therapy
PACE	Promoting Aphasic Communicative Effectiveness
ROI	regions of interest

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extended period of time and training of the affected limb is initiated (induced) over a period of 2 or more consecutive weeks for several hours a day (massed practice principle). Use of massed practice is based on findings from basic animal and human neuroscience research: here, it has been shown that intensive and high-frequent training results in strengthened neural connections between task relevant brain regions, which is thought to be the neural basis of learning and recovery from brain injury.[6,7] Moreover, depending on treatment success, the difficulty of the required motor actions is gradually enhanced (shaping principle) and the training is realized in a behaviorally relevant setting, in which patients are trained in activities relevant to their everyday life (eg, using a spoon, opening doors) in order to enhance transfer. More than 20 years of research in this area, including several large-scale clinical trials, have accumulated a substantial body of evidence that CIMT can improve upper- and lower-extremity impairments in chronic stroke survivors.[1,8] Moreover, it has been demonstrated that these effective treatments induce functionally relevant reorganization of brain networks supporting motor functions.[9]

ADAPTATION OF CI APPROACHES TO TREAT APHASIA

Despite different terminologies used by different work-groups (eg, constraint-induced language or aphasia therapy [CILT/CIAT],[10,11] intensive language-action therapy [ILAN]),[7] CI-based approaches to treat aphasia are based on the findings and principles on which CIMT was founded. Pulvermüller et al[12] were the first to suggest that withdrawal from communication, change of communication strategies, and use of compensatory strategies adopted by many patients with poststroke aphasia could be viewed as a form of learned-nonuse in patients with aphasia. Thus, the original CI-based language treatment protocol encouraged patients with aphasia to focus specifically on communication channels they tend to avoid (ie, verbal communication). As in CIMT, shaping and a highly intensive training environment (usually 3h/d over 10 consecutive days) was established to enhance language relearning and promote neuroplastic reorganization.[7]

To ensure that behavioral relevance of the training is optimized, the therapeutic setting is based on pragmatic and communicative aphasia therapy.[13] Even though implemented with slight variations between work-groups,[10-12,14] the basic setting comprises a therapeutic language game in a group setting.[15] During therapy sessions, up to 3 patients and the therapist perform an interactive card game. At the beginning of the game, pairs of cards depicting object drawings, written words, or drawings/photographs of more complex everyday life scenarios are distributed among the players in a way that none of the players has 2 identical cards. Barriers are used between the players to prevent them from seeing each other's cards, which are typically placed on the surface in front of them.

During the card game, players take turns selecting a card from their own set and asking another player if they have a match. If the other player has the match, he or she will hand it over. The exchange between players (ie, request, response, reply) is expected to be explicit and in most cases involves spoken words or sentences. Some studies strictly enforced the use of spoken verbal expressions (eg, by asking the patients to sit on their hands if necessary),[10] whereas other studies allowed gesturing[16-18] in an effort to exploit the potential of gestures to facilitate language processing.[19,20] Usually, a second therapist is present to help patients with problems that may arise during the game (eg, by prompting with the first letter in case of word finding difficulties) and to provide positive reinforcement. Shaping of language functions is accomplished by introducing increasingly complex materials across training sessions. Performance requirements are enhanced depending on patient's improvements, and different levels of performance are reinforced by the therapist. Every patient is constantly encouraged by the therapist to activate his upper level of language skills. All the studies reviewed in this article had been approved by the respective local institutional review boards.

CLINICAL EVALUATION IN CHRONIC APHASIA (SEE TABLE 1 FOR A SUMMARY)

In 2001, Pulvermüller et al[12] provided the first evidence for the effectiveness of CI-based approaches to improve language functions in chronic aphasia. Ten patients with moderate to severe chronic aphasia (>12mo poststroke) were treated using CI-principles and compared with 7 patients treated with standard aphasia therapy. Patients were randomized either to the CI group that received 30 hours of therapy over 10 days (ie, 3h/d) or to the control group that received the same amount of therapy across 3 to 5 weeks. Both groups underwent comprehensive standardized language testing (Aachen Aphasia Test [AAT] Battery)[21] prior to and after the intervention period and answered a questionnaire about the amount of communication and comprehension in day-to-day communication (Communicative Activity Log [CAL]).[7] The CAL was developed based on a similar instrument used in CIMT studies (Motor Activity Log) and comprises 2 scales that aim to measure the amount and quality of everyday communication by means of self-ratings (patients) or ratings of therapists not involved in the training. Overall language improvements were significant for the CIAT treatment group only (average weighted score of the AAT subscales: Token Test, naming, comprehension, and repetition), with the group receiving standard treatment (extended over a longer period of time) only demonstrating improvement on 1 subtest of the AAT. Additionally, only the patients that received CIAT increased their amount of day-to-day communication as assessed by the CAL. Notably, this effect was found even though time since stroke was shorter in the control group that received standard treatment (mean, 98.2 vs 24.0mo).

In a subsequent study, Meinzer et al[11] replicated these immediate treatment gains in a heterogeneous sample of 27 chronic aphasia patients (time since stroke: range, 13–116mo). Most patients were classified as either having Broca's aphasia (n=11) or Wernicke's aphasia (n=7). The primary outcome measure was the AAT, and single-case analyses revealed significant improvements in about 85% of the patients (ie, significant improvement was found in at least 1 subtest or subscale of the AAT). The patients were reexamined 6 months after treatment termination and both individual and group results demonstrated retention of treatment gains compared with baseline assessment. The amount of day-to-day communication and comprehension, as measured by the CAL, was enhanced after therapy and the patients' relatives rated communicative effectiveness as improved (Communicative Effectiveness Index [CETI]).[22] About 50% of the patients received additional training in day-to-day communication (CIATplus group) in the form of additional exercises completed in the afternoon on each day of training. Exercises were individually arranged to include daily communication practice with a family member and aimed at gradually reestablishing real life communication. While there were no differences between the CIAT and CIATplus groups immediately after training, only the CIATplus group showed further improvement in the rated quality of day-to-day communication (CETI), and only in these patients was the amount of communication and comprehension still above baseline at the follow-up assessment.