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Constraint-induced language therapy for agrammatism: role of grammaticality constraints

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ABSTRACT

Background: Aphasia therapy that involves a high weekly intensity, short overall duration, restriction of nonverbal communication coupled with constraints on verbal complexity, has recently gained momentum (Constraint-Induced Language Therapy, or CILT). The gains have been documented primarily for formal language tests, especially in lexical retrieval, repetition and comprehension measures. Measures of grammatical well-formedness, which have greater ecological validity, have not been commonly reported in prior studies. Further, it is as yet unclear if the nature of verbal constraints has any impact on expressive language outcomes, particularly when the primary deficit in verbal production is grammatical inaccuracy (as in the case of agrammatic aphasia).

Aims: This study aimed to examine if constraint-induced therapy is applicable for individuals with agrammatic aphasia and if the addition of a morphosyntactic constraint would influence expressive language outcomes.

Methods & Procedures: In this phase I study, a single participant design was used with four chronic agrammatic aphasic individuals who received 24 hours of constraint-induced therapy over 10 days, as per prior published protocols. Two of these individuals received additional morphosyntactic constraints regarding tense morphology. Formal aphasia tests, Cinderella story narration, and conversational samples were analyzed at three time points: pre-treatment, post-treatment, and three month follow-up.

Outcomes & Results: While all participants improved on at least some language measures, the overall changes were minimal and not maintained at three months. Participants who received morphosyntactic constraints dramatically improved on an elicited morphosyntactic test, but did not respond differently in other severity and discourse measures. Participants with lower initial language severity scores showed quantitatively larger gains after treatment.

Conclusions: While constraint-induced therapy was minimally effective for the agrammatic participants in this study, and addition of a grammaticality constraint did not significantly enhance the functional outcomes, the findings do indicate that initial severity and aphasic deficit patterns may be useful in determining candidacy for constraint-induced therapy.

There is well-grounded evidence that the intensity and frequency of aphasia therapy play a crucial role in long term outcomes, with high intensity-high frequency therapies providing the most favorable gains in language measures (Bhogal, Teasell, & Speechley, 2003; Robey, 1998). This aspect has been widely embraced in one family of therapies that utilize a triad of principles: massed (intensive) training, constraint of nonverbal communication (typically by using visual barriers between group members), and shaping of verbal responses. Constraint Induced Language Therapy (CILT) or Intensive Language Action Therapy (ILAT) as it has been more recently called (Pulvermuller & Berthier, 2008), involves 24 to 36 hours group engagement of aphasic participants in therapeutic language games (typically over 10 days) (Breier, Maher, Novak, & Papanicolaou, 2006; Maher, Kendall, Swearengin, Rodriguez, Leon, Pingel, Holland, & Gonzalez-Rothi, 2006; Meinzer, Djundja, Barthel, Elbert, & Rockstroh, 2005; Pulvermuller, Neininger, Elbert, Mohr, Rockstroh, Koebbel, & Taub, 2001). Progressively increasing demands are placed on verbal responses that need to be produced and general cueing is provided.

Recent attempts to tease apart the role of intensity versus the content of the treatment have compared CILT with either a group intervention that de-emphasizes verbal production in favor of multi-modality communicative success (Maher et al., 2006), or individual therapy that specifically addresses the participants' linguistic impairment (Barthel, Meinzer, Djundja, & Rockstroh, 2008). Both studies found that, although the high intensity format produced significant changes across all participants, therapy approaches produced differential effects. For instance, therapy focused on multimodality communication was slightly less effective on verbal production scores[1] than therapy with a

[1] As the authors acknowledge, the more frequent occurrence of moderate to severe verbal apraxia in the multimodality group may have limited the potential for favorable verbal gains (Maher et al., 2006; p. 845).

verbal emphasis, which in turn was less efficient than impairment-based therapy (Barthel et al., 2008; Maher, et al., 2006). This suggests that the content of the treatment is perhaps as crucial as intensity, and must be "rational, properly selected, and tailored to the specific aphasic subject's deficits" (Basso, 2005, p. 976). More research is warranted into possible adaptations in the protocol that might render greater communicative improvements. The latter question is critical given that the current CILT protocol is equally effectively administered by trained laypersons and speech-language pathologists (Meinzer, Streiftau, & Rockstroh, 2007), indicating that the expertise of speech language pathologists in administering individual specific intervention may remain untapped with CILT. Given that most CILT efficacy studies have found improvement in comprehension scores, an aspect that is not explicitly targeted in CILT (Pulvermuller et al., 2001; Szaflarski, Ball, Grether, Al-fwaress, Griffith, Nells-Strunjas, Newmeyer, & Reichhardt, 2008), and limited improvements in measures of grammatical production (Szaflarski, et al., 2008, p. 250), more research is warranted into the candidacy for CILT and the underlying basis of language improvements rendered by this therapy.

The language profile associated with agrammatic aphasia, namely a severe impairment in morphosyntactic production with relatively spared conversational comprehension and a fair amount of content word retrieval, is a unique test case for examining candidacy for CILT. This is because the language measures that are reported to improve most significantly in prior CILT studies, such as comprehension scores and noun naming, are relatively less impaired in this group, especially in the relatively pure case of agrammatism (with minimal phonological or apraxic overlay). Further, the adaptation theory of agrammatism (Kolk & Heeschen, 1992) has been used to justify the applicability

of CILT to this population (Pulvermuller & Berthier, 2008, p.570). Two of Szaflarski, et al.'s (2008) participants (HL, FG) evinced telegraphic and fragmented speech with limited morphemes typical of agrammatic aphasia, and failed to improve on a grammatical index measure after one week of CILT.

The goals of this study were two-fold: to examine response to CILT treatment by individuals with agrammatic aphasia, and to examine the potential effect of adapting the CILT procedure to include morphosyntactic shaping. Research on agrammatic aphasia during the past decade has highlighted the relatively greater impairment in tense morphology in comparison to other functional categories (Friedmann & Grodzinsky, 1997; Wenzlaff & Clahsen, 2005). It has also been found that treatment of syntactic structural aspects does not automatically generalize to the production of tense morphology (Dickey & Thompson, 2007). Using a single participant pre- post- treatment design, two individuals with agrammatic aphasia received CILT as per originally published protocols (henceforth referred to as CILT-original or CILT-O) and two additional individuals received CILT in which additional shaping on production and judgment of tense morphology was incorporated (henceforth called CILT-grammatical or CILT-G).

Methods

Participants

Four chronic aphasic participants (one female, age range 44-66 years) with a single left hemisphere cerebrovascular lesion were recruited for the study. All participants gave written informed consent using procedures approved by the Institutional Review Board of the University of Maryland, College Park, and hence this study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All

participants were native speakers of English, right-handed before the lesion, and had at least a high school diploma. None reported prior neuropsychiatric complications, and all were screened for depression. They passed a hearing and vision screen either with or without correctional aids, and their nonverbal memory spans fell within the typical range for individuals with left hemisphere damage and aphasia (De Renzi & Nichelli, 1975). Demographic details of all participants are given in Table 1.

-----Insert Table 1 about here-----

Three out of four participants had a pre-treatment classification of Broca's aphasia as per the Western Aphasia Battery-R (Kertesz, 2007). The exception was P2, whose early initial diagnosis of Broca's aphasia was no longer applicable in the pre-treatment phase due to marked increases in all subtests of the WAB, particularly the spontaneous speech subtest. It must be pointed out however, that at the conversational level, P2 was still severely telegraphic and nonfluent. Narrative speech samples and a variety of morphosyntactic tests were used to determine the presence of an agrammatic speech pattern. Speech samples were elicited using the Cinderella story, Narrative subtests of the Boston Diagnostic Aphasia Examination (BDAE, Goodglass, Kaplan, & Barresi, 2001), and a conversational sample. Characteristics of agrammatic production were evident in all four participants' narratives and were operationally defined as the presence of fragmented utterances, decreased proportion of sentences, paucity of grammatical morphemes and verbs. In addition, all participants were determined to have a difficulty with production of tense morphology, defined as accuracy below 60% on the Verb Inflection Test (Faroqi-Shah, unpublished). P4 was determined to have mild apraxia (as per the Apraxia Battery

for Adults, Dabul, 1979; and the oral expression subtests of the BDAE). None of the other three participants had any degree of apraxia.

Participants were paired on the basis of variety of test measures and sociodemographic variables such that one member of each pair (P1-P3, P2-P4) received a different type of treatment. Since all four participants had been involved in prior research studies, including a treatment study for agrammatic production (Faroqi-Shah, in press, 2008), time elapsed since participation in that study was a crucial factor in equating the pairs.

Outcome measures

The following outcome measures were used to document changes in severity between pre-therapy, post-therapy and follow-up (3 months post-therapy) phases: the Aphasia Quotient (AQ) of the Western Aphasia Battery-Revised (WAB-R, Kertesz, 2007), the Boston Naming test (BNT, Kaplan, Goodglass, & Weintraub, 2000), and the verb naming portion of the Object and Action Naming Battery (OANB, Druks & Masterson, 2000, Form 2, List A). Selection of the above severity measures was based on measures that had been used in prior constraint-induced aphasia studies of English speaking participants (Maher et al., 2006, Szaflarski, et al., 2008). Each participant's percent scores for the three severity measures were used to calculate an overall severity score (t-score) for that participant for each time of testing (as in Pulvermuller, et al. 2001).

The following tests were used to determine changes in morphosyntactic production: the Verb Inflection Test (Faroqi-Shah, unpublished), Cinderella narrative, and an informal conversational sample. The Verb Inflection Test is a 20-item picture description task designed to elicit verbs in past, 3rd person singular present, present progressive, and future

tenses in response to adverbial cues (*Tomorrow, Right now, Yesterday, and Every day/Nowadays*)[2]. Prior use of this test has demonstrated a stable performance over repeated administrations. As is the convention in eliciting Cinderella narratives, participants where shown a wordless picture book to aid in recall of the story (e.g., Rochon Saffran, Berndt, & Schwartz, 2000). The informal conversational sample was elicited in response to small talk such as, *How do you like therapy? What did you do yesterday? How is your family? What are your plans for the holidays?* Morphosyntactic measures were computed by combining the first 15 utterances each from Cinderella and conversational samples (total 30 utterances). These measures included the proportion of sentences (defined as an utterance with a recognizable verb and argument structure), proportion of well-formed sentences (defined as sentences that are accurate in thematic and morphosyntactic aspects, including word order and grammatical morphology), accuracy of tense, and diversity of tense marking (type-token ratio of tense computed as the ratio of unique tense-aspect markings to the total number of verbs). The first two measures (proportion of sentences and proportion of well-formed sentences) are considered syntactic while the latter two measures (tense accuracy and tense diversity) reflect morphological performance. A change exceeding two standard deviations of normative values is typically used as the criterion for significant change for discourse samples (Rochon, Laird, Bose, & Schofield, 2005) and the same criterion was adopted for this study. Normative narrative data were obtained from ten age-matched participants (Faroqi-Shah, unpublished, see also Faroqi-Shah, in press, for a similar procedure).

[2] All participants were pre-tested for comprehension of temporal adverbs using a calendar pointing task, on which they had to identify *yesterday, today, tomorrow, next month,* etc.

All tests were independently scored for accuracy by both authors and a third research assistant who was blind to the treatment conditions. All discourse samples were transcribed by one of the authors and 20% of randomly selected samples were transcribed by an independent research assistant who was blind to the treatment condition and time of testing for reliability purposes. Morphosyntactic codes were independently assigned by both authors. Twenty percent of these samples were also coded by a research assistant for reliability purposes. Coding reliability exceeded 90%.

Intervention

The stimuli consisted of 10 decks of cards with 18 cards in each deck. The decks differed in whether they represented colored objects, multiple objects, and high or low frequency examples of a particular semantic category (animals, fruits, vegetables, clothing, kitchen items, based on Francis & Kucera frequency counts, 1982). All cards were 5”x8” in dimension and represented a person (boy or girl) holding the object(s). There were a large enough number of cards to avoid repetition of any deck during any treatment session.

The procedures described by prior CILT studies (Breier et al., 2006; Maher et al., 2006) were used as a guideline for intervention and these included the three principles of massed training, constraints, and shaping. Massed training was achieved by providing a total of 24 hours of therapy over ten sessions for each CILT pair (P1 and P2 for CILT-O; P3 and P4 for CILT-G). The operational definition of *constraint* was allowing only verbal responses, while all other modes of communication were restricted. A visual barrier was used for this purpose for CILT-O, while CILT-G participants were only given verbal instructions. The dual card game, which has been used in prior studies, was used (e.g., Maher et al., 2006). In this game, participants are dealt cards from a deck and they take

turns in requesting a card to match the cards they already have and in responding to such requests. *Shaping* (also called *focusing* by Pulvermuller & Berthier, 2008) was defined as the use of hierarchically challenging levels to reach the target verbal production. A six-level hierarchy was used with the levels ranging from the use of a simple active sentence (Level 1) to a two-sentence pair consisting of adjectival descriptions and a request (Level 6) (See Table 2). Participants progressed to a more complex level upon successfully producing any level at least twice. The various decks of cards were designed to aid in shaping. Cues were provided by the therapist (the second author) when deemed necessary.

The CILT-O and CILT-G intervention procedures primarily differed in terms of the additional grammaticality constraint used during shaping, as shown in Table 2. A temporal adverb (*Yesterday, Tomorrow, Right now, Nowadays*) was randomly provided to CILT-G participants for each turn and they were required to include the adverb and appropriate verb tense morphology while requesting their cards. For example, an acceptable Level 1 response for CILT-G would be *Yesterday the boy held an apple*, while the minimum criterion for passing the Level 1 for CILT-O would be *Boy hold apple*. It must be pointed out that most of the time CILT-O participants produced more grammatical morphemes than the minimum required, especially determiners and the present progressive tense. Written cues were provided to CILT-G participants during the initial sessions to aid in selection of grammatical morphemes. CILT-G participants were also required to make well-formedness judgments on the verbal requests of their partner. Hence these participants were additionally involved in a comprehension task, an aspect that has not been used in prior CILT studies. Judgment of tense was included in light of evidence that agrammatic

individuals perform poorly in tense judgments (Arabatzi & Edwards, 2002; Dickey, Milman, & Thompson, 2008; Faroqi-Shah, Dickey, & Sampson, 2007).

-----Insert Table 2 about here-----

Results

All four participants demonstrated progress during the treatment sessions, and three participants achieved the highest level of shaping by the end of the treatment period (Level 6 in Table 2). Most participants required almost no cueing after the first three to four sessions. Pre-, post-, and 3 month follow-up scores on all outcome measures are provided in Table 1.

-----Insert Figure 1 about here-----

Severity measures

The overall language severity score, computed as the average of the three measures (WAB AQ, BNT, and OANB) for each participant at each testing time, is shown in Figure 1. The average improvement post-treatment was 2.2 points (range is 0.2 to 3.7; SD=1.5) which is numerically comparable to that obtained by Pulvermuller et al. (2001) (2.0 points) in the first reported CILT study. However, this difference failed to reach significance in our small group sample (Wilcoxon signed ranks test, p=0.1). Three out of four participants maintained (and even exceeded) post-treatment gains during follow-up testing, giving an average gain of 8.8 points that was maintained (range is 0.4 to 16.9; SD=6.7). Figure 1 shows that the largest follow-up improvements were for CILT-G participants. Table 1 shows that the follow-up gains are primarily due to naming scores (BNT, OANB).

Analysis of individual post-treatment test scores (see Table 1) reveals that participants improved significantly (McNemar's change test, p<0.5) on five out of twelve

calculated measures (including WAB AQ, BNT, and OANB), with every participant improving on at least one measure. In follow-up testing, four out of twelve calculated measures were significantly higher than baseline (two being maintained from post-treatment, see Table 1). The WAB AQ was most sensitive to post-treatment changes, with three participants improving in their AQ (range is 5.1 to 24.4). P2 was the only participant whose AQ did not improve, which can be attributed to his near-ceiling performance prior to the initiation of therapy. The participant with the most dramatic improvement in AQ (P3) also had the lowest pre-treatment score. Individual subtest scores of the WAB for each participant are provided in the Appendix. Spontaneous Speech subtests (Information Content and Fluency), which are based on a picture description task, showed the most consistent improvement across all four participants. This suggests that CILT did have a consistent impact on verbal production. Improvements in other subtests (Auditory Verbal Comprehension, Repetition, Naming and Word Finding) were found only for the two CILT-G participants. Following the WAB, performance on the OANB was the next most frequently improved measure and the BNT changed in the least number of instances (McNemar's change test, $p<0.5$).

Morphosyntactic measures

The morphosyntactic values shown in Table 1 are combined over Cinderella narrative and conversational speech because there were no reliable differences between these two tasks. Due to experimental error, P3's post-treatment Cinderella narrative was unavailable and a narrative sample from the BDAE was used in lieu of the Cinderella narrative. Overall, participants improved significantly on four post-treatment and two follow-up testing discourse measures respectively out of the 16 obtained each time

(criterion of two standard deviations from normative values). An inspection of individual discourse measures reveals that no single measure was more consistently sensitive to change. Only two participants, P2 and P4, improved on more than one discourse measure, and there is no discernable response pattern distinguishing CILT-O and CILT-G participants. It must be pointed out that only morphosyntactic measures are reported here. Lexical measures such as total number of words and type-token ratio, structural measures such as mean length of utterance, and fluency measures such as rate of speech were also inspected and there were no significant and consistent changes[3]. Hence these are not reported here.

The Verb Inflection Test showed significant improvements in post-treatment and follow-up tests for P3 and P4, both received CILT-G (McNemar's change test, $p<0.05$). The two CILT-O participants (P1 and P2) showed no significant change in this measure. It must be pointed out that the elicitation of tense morphology in the Verb Inflection Test closely parallels the grammaticality constraint placed in CILT-G because both situations require the participant to produce verbal morphology in response to a temporal adverb. These findings indicate that the use of a grammaticality constraint gave the CILT-G participants a significant advantage in the Verb Inflection Test.

Discussion

This phase I treatment study aimed to determine the applicability of CILT to the rehabilitation of individuals with agrammatic aphasia, and to examine the effect of incorporating a grammaticality constraint into the shaping hierarchy. These questions were addressed using a variety of severity and morphosyntactic outcome measures. The results

[3] All of these measures were additionally analyzed for two other discourse samples, BDAE's narrative subtests and description of an animated cartoon (Tom & Jerry ®). Again, there were minimal significant changes that did not consistently reveal a pattern.

with four agrammatic individuals revealed improvements in severity scores, especially in the Western Aphasia Battery Aphasia Quotient. However, changes in the overall language t-scores computed over multiple tests, were non-significant. Narrative measures showed scattered changes that did not fall into any consistent pattern. Differences between response to CILT-O and CILT-G were apparent in one respect: the marked superiority in post-treatment performance of CILT-G participants on the Verb Inflection Test.

Three conclusions can be drawn from these findings regarding the applicability of CILT for individuals with agrammatic aphasia. First, modest changes in severity test measures are observed and these changes are not quantitatively dissimilar to those reported in some other studies for a more heterogeneous aphasic population (Pulvermuller et al., 2001). However there is a likely confound of severity, with an inverse relationship between initial language severity and post-treatment improvements with CILT. This is consistent with prior studies. For example, in a study by Szaflarski et al. (2008), participant HL, with a pre-treatment severity score of 69.15 failed to improve with CILT, while JL, whose pre-treatment severity score was zero, showed a 13 point increase (Szaflarski et al., Table 1). Hence it is likely that severity may be a crucial factor in predicting response to CILT. When comparing our participants with those of prior CILT studies (Breier et al., 2006; Maher, et al., 2006, Pulvermuller et al., 2001), it is apparent that our participants are less impaired. For example, the average pre-treatment performance score in Pulvermuller et al. (2001) was 53.5, while it was 76.5 in the present study.

The second finding is that morphosyntactic structural measures from narrative speech showed little change. Two prior studies that reported narrative data for CILT also found a mixed pattern of results (Maher et al., 2006; Szaflarski et al., 2008) and no

consistent differences between CILT and multimodality intervention (Maher et al.). Hence the pattern to date has been little quantitative and qualitative change in narrative speech. It must be pointed out that this contrasts with the subjective perception of improvements in communication by caregivers (Pulvermuller et al.; Maher et al.). Perhaps after receiving CILT, participants are less likely to avoid partaking in social conversations although the linguistic sophistication of their verbal output may not be substantially different.

The third finding of this study is that participants who received CILT-G responded positively to the morphological constraints incorporated in the protocol. However, this effect was found only in the elicited test and did not generalize to narrative speech. Although, more research is warranted before conclusive interpretations can be made, response to CILT-G was not dissimilar (albeit less promising) to what is reported with impairment based interventions for agrammatism: improvements in specifically targeted morphosyntactic structures in elicited tasks, and in general severity measures, but limited generalization to spontaneous discourse (Faroqi-Shah, in press; Mitchum & Berndt, 1994; Thompson & Shapiro, 2005).

The primary implications regarding candidacy for CILT from this small group of agrammatic participants (and comparisons with individual participant data from prior studies) dampen the prior overarching enthusiasm for CILT as a “one size fits all” therapy (see Sunderland & Tuke, 2005; for similar discussions with motor rehabilitation). The core morphosyntactic production deficits of agrammatic aphasia appear to be somewhat resistant to change with CILT. Some other factors that need to be considered in determining candidacy for CILT are the overall severity (magnitude of change inversely associated with initial severity, although Meinzer et al., 2005, report no effect of severity)

and the pattern of impairments, particularly with reference to content word retrieval (low pre-treatment scores translate to greater post-CILT increases), auditory comprehension and concomitant apraxia (the latter two factors limit participation in group activities). Considerably more research needs to be directed towards identifying prognostic predictors for CILT, especially given the practical hurdles in implementing CILT in clinical settings (see Sterr, Szameital, Shen, & Freivogel, 2006).

The need to delineate the specific contribution of each of the three core components of CILT has begun to be addressed by aphasiologists (Barthel et al., 2008; Maher, et al., 2006). It is noteworthy that, when intensity is matched, impairment based approaches yield more positive outcomes (Barthel et al.). The inclusion of the grammaticality constraint in CILT-G was one such attempt at impairment-based shaping. However, the effects were limited to elicited tasks, and did not generalize to discourse. More research is needed to determine which adaptations and shaping procedures are most effective and what is the likely trade-off between general language-game stimulation and deficit-tailored techniques. This need for documenting responses to CILT was stated by Pulvermuller and Berthier (2008), “it appears of utmost interest to widen the range of communication types in Intensive Language Action Therapy and determine efficacy and applicability to specific aphasia types for each therapeutic language game individually” (p. 579).

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APPENDIX

Breakdown of scores on the Western Aphasia Battery (Kertesz, 2001).

WAB subtests	P1			P2			P3			P4		
Treatment type	CILT-O			CILT-O			CILT-G			CILT-G		
	Pre-Tx	Post-Tx	FU	Pre-Tx	Post-Tx	FU	Pre-Tx	Post-Tx	FU	Pre-Tx	Post-Tx	FU
Information content/10	9	10	10	10	10	10	8	10	10	8	10	10
Fluency/10	5	6.5	6	9	10	9	5	9	9	5.5	8.5	9
Auditory verbal compr./10	7.45	8.1	6.65	9.85	9	9.15	6.85	8.95	9	10	9.4	9.45
Repetition/10	5.8	5.2	5.2	9.2	8.8	9.3	5.2	7.6	7.5	7	6.2	6.5
Naming & word finding/10	7.6	7.6	7.5	8.8	8.6	8.7	6.4	8.1	7.9	7.4	8.4	8.3
Aphasia Quotient /100	69.7	74.8*	70.7	93.7	92.8	92.3	62.9	87.3*	86.8*	75.8	85*	86.5*

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Table 1. Participant information and outcome measures.

Demographics	P1			P2			P3			P4		
Age/Gender	68years/Female			56years/Male			62years/Male			45years/Male		
Education	16			13			20+			18		
Profession	Office clerk			Insurance clerk			Self-owned business			Software Engineer		
Months post onset	138			24			59			24		
Months post morphosyntactic Tx	23			7			23			5		
Treatment type	CILT-O			CILT-O			CILT-G			CILT-G		
	Pre-	Post-	FU	Pre-	Post-	FU	Pre-	Post-	FU	Pre-	Post-	FU
Severity Measures												
Aphasia Quotient /100	69.7	74.8*	70.7	93.7	92.8	92.3	62.9	87.3*	86.8*	75.8	85*	86.5*
Boston Naming Test /60	47	36	46#	56	58	58	28	20	31#	52	54	60
Object & Action Battery /50	38	47*	39	37	41*	48*	34	34	45*#	46	40	49#
Morphosyntactic Measures												
Proportion sentences	0.6	0.77	0.6	0.53	0.46	0.53	0.53	0.5	0.6	0.4	0.36	0.06
Proportion well-formed sent.	0.4	0.43	0.33	0.2	0.26	0.5^	0.2	0.3	0.3	0.03	0.2	0
Tense accuracy	0.88	0.93^	0.9	0.75	0.84	1	0.75	0.69	0.81	0.71	0.77	0.5
Tense diversity	0.33	0.26	0.27	0.16	0.3^	0.36^	0.25	0.38	0.27	0.28	0.44^	1$
Verb inflection test /20	4	5	5	8	9	7	8	14	12	8	12	10

*Pre versus post-treatment comparison ($p<0.05$), Mc Nemar's change test; #Followup versus post-treatment comparison ($p<0.05$), Mc Nemar's change test; ^ 2SD change from normative values (N =10; Mean and SD are given in parenthesis).

Table 2. Hierarchical levels of constraints used for shaping, with examples and minimum passing criteria.

Levels	CILT-O	CILT-G
		A temporal adverb was provided for all levels
Level 1: agent + action + object	Boy hold apple	Yesterday the boy held the apple.
Level 2: Level 1 + request	Boy hold apple. Card?	Yesterday the boy held the apple. Can I have that card?
Level 3: Level 2 + polite request	Boy hold apple. Bob, card please?	Yesterday the boy held the apple. Bob, can I have that card please?
Level 4: Level 3 + color adjective	Boy hold red apple. Bob, card please?	Yesterday the boy held the red apple. Bob, can I have that card, please?
Level 5: Level 4 + article	The boy hold the/a red apple. Bob, card please?	Yesterday the boy held the/a red apple. Bob, can I have that card, please?
Level 6: Level 5 + plurality	The boy hold two red apple. Bob,	Yesterday the boy held two red apples.

card please?	Bob, can I have that card, please?

Figure Legend

Figure 1. Language t scores for each participant, calculated as the average of three test scores (WAB AQ, BNT, OANB) for each time period.

Figure 1. Language t scores for each participant, calculated as the average of three test scores (WAB AQ, BNT, OANB) for each time period. Solid lines represent participants who received CILT-O, dotted lines received CILT-G.