Automated Constraint-Induced Therapy Extension (AutoCITE)
for movement deficits after stroke

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Abstract—We report progress in the development of AutoCITE, a workstation that delivers the task practice component of upper-limb Constraint-Induced Movement therapy and that can potentially be used in the clinic or the home without the need for one-on-one supervision from a therapist. AutoCITE incorporates a computer and eight task devices arranged on a modified cabinet. Task performance is automatically recorded, and several types of feedback are provided. In preliminary testing, nine chronic stroke subjects with mild to moderate motor deficits practiced with AutoCITE for 3 h each weekday for 2 weeks. Subjects wore a padded mitt on the less-affected hand for a target of 90% of their waking hours. In terms of effect sizes, gains were large and significant on the Motor Activity Log, and moderate to large on the Wolf Motor Function Test. These gains were comparable to the gains of a matched group of 12 subjects who received standard Constraint-Induced Movement therapy.

Key words: automated rehabilitation, cerebrovascular accident, CI therapy, Constraint-Induced Movement therapy, movement, upper limb.

INTRODUCTION

There are at least 600,000 strokes every year in the United States, and stroke is the leading cause of disability [1,2]. Stroke-related motor deficits and disabilities result in compromised quality of life, lost independence, and enormous healthcare costs [3,4]. Two controlled trials and numerous studies from a number of laboratories have shown that Constraint-Induced Movement therapy, or CI therapy, increases the amount of use of the more-affected upper limb in activities of daily living (ADLs) in patients with mild to moderately severe chronic stroke [5,6]. However, CI therapy is an intensive intervention that involves a great deal of one-on-one therapist time and is therefore too expensive to be available for many individuals who would benefit from it. The aim of our research was to determine if CI therapy could be automated, thereby reducing the need for costly therapist time and consequently making the intervention available to a larger number of persons than is presently possible. This

Abbreviations: ADL = activity of daily living, ANOVA = analysis of variance, AOU = amount of use, AutoCITE = Automated Constraint-Induced Therapy Extension, CI = constraint-induced, MAL = Motor Activity Log, QOM = quality of movement, WMFT = Wolf Motor Function Test.

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study is viewed as a first step in developing a device that could administer CI therapy in the home; it would be a form of “telerehabilitation,” where contact with the therapist would be on a remote, periodic, and attenuated basis.

CI therapy involves promoting use of the more-affected upper limb by restraining the less-affected limb for a target of 90 percent of waking hours for 2 to 3 consecutive weeks (depending on the severity of the deficit) with a padded mitt that prevents use of the hand in ADLs. In its most common form, the patients receive a type of training called “shaping” for 6 h per day (with rest intervals interspersed as needed) for all weekdays during the training period (concentrated training). Shaping is a widely used behavioral training technique in which a desired motor or behavioral objective is approached in small steps, by successive approximations [7–11]. In many ways, shaping is a formalization and systematization of procedures already used by therapists when giving patients task practice. Frequent explicit verbal feedback is provided for small improvements in performance, and performance regressions are ignored. A subset of tasks from a large bank of tasks is selected for each patient. All tasks are easily quantifiable, so that small improvements are immediately apparent to both the patient and therapist.

We report progress in the development of AutoCITE (Automated Constraint-Induced Therapy Extension), a workstation that can potentially deliver the shaping training portion of CI therapy to patients without the need for one-on-one supervision from a therapist. This would substantially reduce the cost of CI therapy by allowing patients to perform the exercises at home or by having one therapist treat four or more patients simultaneously in the clinic. The reduced cost would greatly expand the pool of individuals who could receive the intervention. These advances in the delivery of CI therapy are significant, given the current healthcare climate of cost containment, where the provision of services by healthcare payers is being cut back sharply for inpatient and outpatient physical rehabilitation therapy. AutoCITE would also provide clear and comprehensive quantification of the progress of the treatment. This would indicate on which tasks the patient was progressing most and least rapidly, and enable rapid and effective modifications of the treatment plan while treatment was in progress.

The primary goal of this preliminary testing was to determine if interposing the AutoCITE between the subject and the therapist compromises the effectiveness of the training procedure. Three factors might diminish AutoCITE’s effectiveness relative to standard one-on-one shaping with a therapist. First, in standard CI therapy, the therapist can choose from a bank of well over 100 tasks, and can customize the tasks employed for each subject by creating new tasks that might be particularly useful or motivating. In contrast, the AutoCITE currently only has 8 tasks implemented. Second, therapists have considerably more flexibility in shaping a task relative to the shaping options implemented in this version of the AutoCITE. Third, the patients must interact with a computer, which could be less motivating than receiving one-on-one attention from a therapist. We had the therapist present during all the training sessions in this preliminary study in order to ensure the smooth functioning of this new procedure. However, the sessions were arranged so that the therapist supervised the interactions between the subject and AutoCITE instead of administering the training directly. For example, instructions and encouragement for the subject were issued predominantly by the computer, with the therapist interjecting comments occasionally to supply additional encouragement, or if the subject became confused or could not understand the instructions.

The specific question addressed in this study was whether a group of stroke subjects given CI therapy by means of AutoCITE would achieve as large a treatment effect as a group of subjects who received CI therapy in a nonautomated setting. Both groups were equivalent in all significant demographic characteristics and had similar initial upper-limb motor deficit. The long-term objective of our work is to develop a workstation that can be operated entirely by the subject, without a therapist overseeing the session.

METHODS

AutoCITE Workstation

In the present setup, a computer provides simple one-step instructions on a monitor that guides the subject through the entire treatment session (Figure 1). Sensors built into the workstation verify completion of each instruction before the next instruction is given. Since hand function will be compromised initially in all subjects and the less-impaired hand will be in a mitt, the workstation is designed to be operated with gross movements at each of the joints. A rotating arm is attached to the subject’s chair and is swung in front of the subject during the session.
The rotating arm has two pushbuttons that are used by the subject when a choice is to be made and to allow the subject to control the flow of the session by informing the computer that he/she is ready to move to the next step. Data are collected by a computer that is equipped with a digital input/output PC card (PC-DIO-96, National Instruments, Austin, TX), and an encoder reader PC card (PC7166, US Digital Corp., Vancouver, WA). All software was custom-written in the C programming language.

Currently, eight tasks have been automated. Each task device was custom-manufactured and uses simple and inexpensive means to record performance during the exercise. The activities are based on tasks currently used in CI therapy and collectively address shoulder, elbow, hand, and wrist function. The eight task devices are arrayed in a cabinet on four tiered work surfaces, whose height is automatically adjusted when a task is selected to be worked on. Each work surface can be manually pulled out and locked over the subject’s lap. Two tasks are located on each work surface. The top work surface can be pulled out and locked in three positions, allowing adjustment of the distance from the subject to the device. Switches detect the position of each work surface. Subjects sit in a customized chair that can be moved to different distances from the table and locked into place, depending on the arm length of the subject. The chair can also rotate and be locked at several angles. A digital shaft encoder (E2 Optical Kit Encoder, US Digital Corp.) measures the angle of the chair, and a limit switch detects the flex of the chair as the subject leans back against the seat. Data from the latter sensor are used by the computer program to sound a buzzer when subjects are leaning forward during task practice. A computer monitor with a touch screen (Entuitive 1725C, Elo TouchSystems, Fremont, CA) is located on the top shelf and has multiple functions: display of the menu for task selection, provision of various types of performance feedback, display of instructions for the subject to set up and perform each task, and display and interface for two tasks that involve the touch screen directly. The constraints of the apparatus require that the task be performed correctly, within limits, and deviations from prescribed performance are recorded.

At the beginning of each session, all work surfaces are pushed all the way in. The subject uses the buttons on the rotating arm to select a task from the menu displayed on the computer monitor. The computer program controls a motorized linear actuator (Desk lift DL1, Linak Inc., Louisville, KY) that automatically moves the workstation up or down, stopping when the appropriate work surface is positioned at lap level. The subject then pulls the work surface out, locks it in place, and begins the task. The computer program guides the subject through a set of ten 30 s trials with the selected task. The subject is instructed to repeat a task as many times as possible within each 30 s trial interval. Final feedback for that task is presented and the task menu is then displayed, making it possible for the subject to select the next task.

Several types of performance feedback are provided. The time remaining on each trial is shown to the subject on the computer monitor by a circular display whose filled area progressively increases along a moving radius line as time elapses. The computer produces an audible beep when a repetition is completed. The number of repetitions of the required task movement is displayed to the subject after each trial in the form of a new bar on a graph containing a bar for each trial in that set (Figure 2). The height of the bars is proportional to the number of repetitions of the task in each trial; in addition, the number of repetitions is displayed as an Arabic numeral above each bar. A horizontal red line across the bar graph indicates the best previous single trial performance for that task, while a horizontal
blue line indicates the mean performance of the previous set of 10 trials. Our observation was that the subjects tended to pay more attention and receive more performance motivation from the end-of-trial display than from the within-trial elapsed time indicator. Encouraging comments, such as “Wow,” “That’s a new record,” or “Keep up the good work,” are provided by the computer when a new best performance is attained for all trials of that task. Two other sets of comments are used to encourage subjects if performance is well below average (e.g., “Let’s keep trying,” “Ready for another try”) or if performance is not a new best, but is better than the average on the previous set (e.g., “Well done,” “Good work”). Data are collected at 250 Hz and stored for later examination.

While the goal was to have the subjects operate the workstation without physical assistance from the therapist, one aspect of the workstation, related to changing from one task to another, could not be easily performed by some subjects with their more-affected limb in this prototype device; locking, unlocking, and pulling out the work surfaces required more arm function than most of the subjects possessed and was therefore carried out by the therapist. Also, it was found that the increments in the positions of the top work surface were too large to be used as a shaping parameter for the reaching and tracing tasks. Therefore, in order to increase the distance of the monitor from the subject, the therapist positioned it manually in inch increments. The weight of the monitor prevented any movement of the work surface resulting from contact with the touch screen during task performance. However, all subjects carried out all other aspects of task setup without assistance from the therapist.

During testing with the device, the therapist supervised the session by operating the keyboard of the computer and providing verbal encouragement to the subject when needed. He could bring up a special display screen that presented the subject’s performance from all trials of a particular task since the beginning of the 2-week treatment. The therapist also used the keyboard to modify the difficulty of each task using the principles of CI therapy shaping. A brief description of each task follows (Figure 3).

**Reaching**

This task involves successive tapping of a button positioned on the rotating arm just in front of the body and a target circle located on the touch screen monitor. When the touch screen is touched, a conductive coating on a transparent cover sheet makes electrical contact with a conductive coating on the glass of the monitor. This produces voltages that are analog representations of the position touched. This position information is transmitted by the touch screen controller to the computer via a serial port connection. Feedback consists of an audible beep when the target is touched and by filling in the target circle on the monitor. Performance is measured as the number of completed cycles, and task difficulty can be increased by moving the monitor further away or higher, decreasing the size of the target, or rotating the chair of the subject so that the target is located more laterally.

**Peg Board**

The task is to move three pegs from a row of holes to a mirror-image row of same-sized holes on the other side of the board and then back again, etc. Each peg has a magnet embedded in its base. Reed switches in the holes measure when a peg is in place. These reed switches are normally open, and they close when a magnetic field is close by. Three sizes of pegs are used with a row of corresponding sized holes on either side of the board. The tallest and largest diameter pegs (11.6 × 3.7 cm) require cylindrical grasp forprehension, the intermediate size (7.2 × 2.0 cm) require three-jaw-chuck grasp, and the smallest cylinders (3.4 × 0.6 cm) require thumb-index finger pinch. Performance is measured as the number of pegs moved in 30 s.
Subjects grasp a cylindrical handle that is mounted to a shaft and bearing assembly that allows rotation about an axis through the forearm. A digital shaft encoder measures the position of the handle, and an electromagnetic brake on the shaft coupled to the encoder simulates mechanical stops by engaging when a particular angle is exceeded in each direction. Subjects rotate the handle back and forth between these two stops. Performance is measured by the number of completed cycles in 30 s. Difficulty is increased by engaging the brake at greater angles so that larger excursions of supination and pronation are required to complete the task.

**Threading**

The task is to thread a shoelace through holes near the tops of a series of posts (7.5 × 2.5 cm) arranged in two parallel rows. This requires pushing the tip of the shoelace through a hole, reaching around to the other side of the post, regrasping the tip and pushing it through the next hole, and so on. Reed switches in each post measure when a magnet near the tip of the shoelace has been moved through each hole. The holes are 0.7 cm in diameter, but they differed on the two sides of the post. On one side of the post, the entry to the hole was chamfered (outer diameter 1.4 cm) so that the threading of the shoelace was facilitated, while on the other side the rim of the hole was unaltered. Performance was the number of holes threaded in 30 s.

**Tracing**

The touch screen presents large block letters that the subject has to trace with his/her fingertip or other portion of the hand. Feedback is provided by a filling in of segments surrounding the touched portions of the letter as the tracing proceeds. Difficulty is increased by decreasing the width of the letters, increasing the distance of the monitor from the subject, or increasing the height of the monitor. Performance is measured as the number of completed letters in 30 s.

**Object-Flipping**

The goal was to repeatedly flip over a rectangular block selected from a set of blocks whose dimensions
range from 22.5 × 1.2 × 1.3 cm to 23.0 × 5.0 × 2.8 cm. The object has to be kept on a rectangular work surface (41 × 23 cm). One side of the block is painted blue and the opposite side is painted red. A video camera (V-XA095, Marshall Electronics, El Segundo, CA), video-to-VGA Converter (Cheese Video Box, Omega Multimedia, Orlando, FL), and custom color-discrimination circuitry detects the ratio of blue to red in the visual field to determine when the object has been flipped. Performance is the number of flips in 30 s. To increase difficulty, progressively smaller blocks are typically used, although some subjects have difficulty extending the fingers so that flipping larger objects is more challenging.

**Fingertapping**

Five stainless-steel pads are fastened to rare-earth magnets that are arranged on a metallic surface so that each fingertip contacts one pad when the hand is placed flat on the surface. A metal-oxide semiconductor field-effect transistor (ZVNL110A, Zetex Semiconductors, Oldham, UK) connected to each pad detects when each finger is in contact with its corresponding pad. The task is to tap one finger as fast as possible. Performance is the number of taps in 30 s. A height-adjustable doorknob is located beneath the palm of the hand; subjects have to keep the palm of their hand in contact with this doorknob during the tapping. For subjects with spasticity, the doorknob can be moved upward relative to the fingertip pads, so that the task can be completed with the fingers in a more flexed position. Any of the fingers can be tested, but because of time constraints, only one finger is tested in each session.

**Arc-and-Rings**

This task device mimics the arc-and-rings device used in conventional physical rehabilitation. A ring is attached to the end of a long arm that is mounted to a bearing assembly that allows rotation of the arm in the frontal plane between two fixed mechanical stops located on either side of the subject close to the horizontal. A digital shaft encoder measures the position of the arm of the device. The task is to grasp the ring and rotate the arm of the device from one mechanical stop to another. Difficulty is graded by an increase in the length of the arm of the device. Performance is the number of completed cycles in 30 s.

**Clinical Testing**

To evaluate whether automated CI therapy produced outcomes that were similar to those produced by therapist-administered CI therapy, we compared data from the subjects who received treatment using AutoCITE to data from 12 subjects who received an equivalent amount of standard CI therapy. The nine individuals (seven males, two females) in the AutoCITE group were a mean of 50.9 yr old (range = 26.1–66.2 yr) and had sustained a cerebral vascular accident more than 1 yr earlier (mean chronicity = 5.1 yr, range = 1.7–14 yr). The more-affected side was the right side for six participants and the left side for the other three. All participants were right-hand dominant prior to stroke. The 12 participants (7 males, 5 females) in the standard CI therapy group were a mean of 51.5 yr old (range = 25.4–75.5 yr) and had experienced a stroke more than 1 yr earlier (mean chronicity = 3.4 yr, range = 1.2–15.7 yr). The more-affected side was the right side for six participants and the left side for the other six. Of the 12 participants, 10 were right-hand dominant prior to stroke. The dominant side of the body was more impaired for six participants. All could extend at least 20° at the wrist and 10° at each of the metacarpophalangeal and interphalangeal joints, while at the same time having greatly reduced use of the limb in ADLs. Subjects were excluded if they had balance problems, excessive pain in any joint of the limb, uncontrolled medical problems, excessive spasticity, or cognitive problems, as indicated by a score on the Mini-Mental State Exam of less than 24 [12]. The protocol was approved by the Institutional Review Boards of the Birmingham and Palo Alto VA Medical Centers, where the work was carried out. Each patient received a detailed description of the protocol and signed an informed consent form. The standard CI therapy subjects were recruited from the same subject pool as the AutoCITE subjects, with the same intake criteria; there were no significant differences between the two subject groups in age, time since stroke, gender, race, side of paresis, or dominance.

All subjects were asked to wear a padded safety mitt on their less-affected limb for a target of 90 percent of their waking hours over a 2-week period [5]. Each weekday during this period, subjects in the AutoCITE group received shaping using the AutoCITE device for 3 hr, with another half hour or so for testing and record-keeping activities. A therapist experienced with CI therapy supervised the sessions. Rest intervals were given at the discretion of the therapist. The AutoCITE subjects received a mean of 3.9 tasks per hour (39 30 s trials each hour). The standard CI therapy subjects received shaping for the same duration of time.

For all subjects, testing was carried out just before and immediately after the 14-day intervention period. The
tests included the Wolf Motor Function Test (WMFT) [12,13] and the Motor Activity Log (MAL) [12]. The WMFT measures performance time on 15 tasks and the strength of forearm flexion and grip in two tasks. Subjects are requested to carry out the tasks in a laboratory setting. The MAL is a semistructured interview that provides a measure of spontaneous use of the more-affected upper limb in the life situation. It obtains information about common and important ADLs from such areas as feeding, dressing, and grooming, providing scores on a “How Much” scale and a “How Well” scale. The version employed here had 14 items. Details about the treatment and testing procedures can be found elsewhere [7,12,14].

Data Analysis
Repeated measures analyses of variance (ANOVAs) were used to analyze the data. The effect of treatment was evaluated as a within-subjects factor (Treatment; levels = pretreatment, posttreatment); the effect of treatment modality was evaluated as a between-subjects factor (Modality; levels = AutoCITE, standard CI therapy). The principal experimental question, whether there were differences in outcomes between the AutoCITE and standard CI therapy groups, was evaluated by testing the interaction effect (Treatment × Modality) and calculating 95-percent confidence intervals (lower limit to upper limit). Two-tailed tests with an alpha of 0.05 were used. Effect sizes were indexed using Cohen’s $d'$ (small $d' = 0.14$, medium $d' = 0.36$, large $d' = 0.57$) [15]. Standard deviations (SDs) are reported in parentheses. Data from an AutoCITE participant that displayed Parkinsonian symptoms were excluded from the analyses; WMFT data from a standard CI therapy subject whose post-treatment score was an outlier (>3 SD above the mean) were also excluded.

RESULTS
All subjects completed the treatment and evaluations. Examination of the data showed that subjects had rapid gains within the training tasks. Figure 4 summarizes data from a single subject in the peg board task over the 2-week training period. Gains in terms of number of repetitions were apparent in the first week of training, even though the task moved from the requirement for a cylindrical grasp to a three-jaw-chuck grasp. Difficulty was increased by moving to a thumb-index finger pinch, but performance nevertheless stabilized at approximately double the number of pegs moved at the start of training. A total of 4,190 pegs were moved over the 2-week period. Figure 5 compares best performance on the tracing task on days 1 and 10 for a single subject. By test day 10, both quality of movement and speed were substantially improved. The A-B-C letter sequence was performed in 20 s on day 1 and 10.8 s on day 10. This was all the more impressive considering that the task was much more difficult on day 10 compared to day 1: the monitor was 20.3 cm further away and 5.1 cm higher. These two examples are representative of the typical pattern of improvement seen in the other tasks and the other subjects.

Participants from both AutoCITE and standard CI therapy groups showed very large improvements in real-world arm function as measured by the MAL, and moderate to large improvements in arm motor ability as measured by the WMFT. On the MAL, participants from both groups combined showed on average a 2.2 (0.4) point increase in more-impaired arm quality of movement (QOM) ($p < 0.0001, d' = 5.5$), going from a score of 1.1 (0.5) pretreatment to 3.2 (0.6) posttreatment. Participants also displayed a 2.2 (0.6) increase in more-impaired arm amount of use (AOU) ($p < 0.0001, d' = 3.7$), starting with a score of 1.0 (0.5) pretreatment and ending with a score of 3.2 (0.7) posttreatment. On the WMFT, participants from both groups combined exhibited a 2.9 (5.6) s decrease in performance time ($p < 0.05, d' = 0.5$), going from 6.2 (7.2) s pretreatment to 3.4 (2.6) s posttreatment.

Most importantly, with respect to the primary question addressed in this experiment, there were no significant differences in the amount of improvement displayed by AutoCITE and standard CI therapy subjects (nonsignificant
Treatment $\times$ Modality interaction). This result was confirmed by inspecting the confidence intervals around the mean change from pre- to posttreatment on each treatment outcome for each treatment modality. The confidence intervals on each treatment outcome overlapped, which suggests that automated CI therapy produces outcomes that are approximately equivalent to those of standard CI therapy. For AutoCITE and standard CI therapy subjects, mean changes in (1) MAL QOM scores were 2.0 (1.7 to 2.3) and 2.2 (2.0 to 2.5), respectively; (2) MAL AOU scores were 1.9 (1.4 to 2.4) and 2.3 (1.9 to 2.7), respectively; and (3) WMFT performance time scores were $-3.3$ (1.0 to $-7.6$) and $-2.5$ (1.3 to $-6.2$), respectively. No significant differences on these measures were found between the AutoCITE and standard CI therapy subjects before treatment.

DISCUSSION

These results represent a successful first step toward the development of a take-home automated workstation capable of delivering CI therapy without direct supervision from a therapist. Comparison of our results with those of other studies from the University of Alabama at Birmingham laboratory strongly suggests that there was no loss of effectiveness when the AutoCITE was interposed between the subject and the therapist. It was somewhat surprising that subjects who trained in AutoCITE improved as much as subjects who received one-on-one treatment from therapists. AutoCITE has far fewer tasks available, has limited shaping options, and decreases the intimacy of the interaction between patient and therapist. These potential deficiencies may have been offset by AutoCITE’s capability to provide more consistent and detailed performance feedback with each trial. The results are consistent with the hypothesis that the key therapeutic factor of CI therapy is the actual amount of concentrated use of the limb, rather than the context of the training, the type of tasks used, and the one-on-one attention of therapists. These factors appear to be of secondary importance, but work is needed in the future to evaluate this experimentally. While these aspects of the training may be important to motivate some subjects to perform the concentrated training required by CI therapy, the immediate and continuous feedback and encouraging phrases provided by AutoCITE appeared to be sufficient to produce equivalent results to those achieved by subjects treated in a nonautomated setting. This was evident for the mild to moderately impaired subjects studied.

Figure 5.
Performance of a letter tracing task on first day (top row) and last day (bottom row) of training. By day 10, the computer monitor was 20.3 cm farther away and 5.1 cm higher than on day 1. Gaps in the tracings indicate times when the finger was lifted off the surface of the monitor.
here, but further examination is needed to test the effectiveness of AutoCITE in more severely impaired subjects.

Our overall goal is the development of a home-based system. To this end, several modifications to the AutoCITE are in order. Most importantly, the user interface will undergo continued development. The next iteration of the user interface will have a game-like feel that will increase adherence to the concentrated training requirement when the therapist’s presence is decreased or removed entirely. Also, an autoshaping algorithm will be developed. Data collected from testing subjects in AutoCITE while supervised by a therapist will be used to develop this algorithm. These data will provide information on when and under what conditions the therapist increased or decreased the difficulty of the task. For a home-based device, the size of the system will need to be decreased so that it can be easily transported to and quickly set up in a subject’s home.

Our plan for how the home-based version of AutoCITE will be used is as follows. As subjects receive device-based training at home, performance data will be continuously transmitted from AutoCITE to a base-station computer located at a central laboratory facility through a modem-to-modem connection. This will provide access in the clinic to an online flow of data from the shaping training. A therapist at the central laboratory will periodically monitor the performance data to assure adherence to protocols. A video camera will be incorporated into the home workstation that continuously records performance. If the therapist notices erratic performance on a task, he/she might want to investigate this further by examining visual images of the exercise. Upon request by the monitoring therapist, video of the trials in question will be downloaded to the base-station computer at the central laboratory via the modem-to-modem connection. The therapist could then program changes in the subject’s treatment protocol, or send instructional messages over the modem-to-modem connection. In future applications, a therapist could thereby monitor 4 (and perhaps more) subjects at a time, interacting with individual subjects as time permits and as difficulties in the training emerge.

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REFERENCES


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