Effects of Video-Based raining on Traumatic Brain Injury Patients

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Abstract

Video and computer based therapy techniques have become popular in treating different conditions of the visual system. Traumatic brain injured (TBI) patients might be a population that could benefit from such therapy. A pilot study assessed the effect of video-based training on TBI patients. Two patients with moderate to severe TBI and one patient with brain surgery were recruited. Computer video-based cognitive training procedures were developed. Training was administered weekly over a 12-week period. Reaction time and correctness of response were quantitatively assessed. Patients' reaction time decreased exponentially during the training period, reaching an asymptotic level of about 2 sec. This level was, however, still higher than the 1 sec level found in control subjects. The findings indicated that TBI patients exhibit a cognitive deficit as compared to normals. Moreover, their responses cannot be characterized as being similar to a fatigue condition in normals.

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Key Words

acquired brain injury, computer based therapies, video based training

INTRODUCTION

There are approximately 1.4 million people in the United States who suffer from traumatic brain injury (TBI).[1] These injuries can have devastating consequences resulting in severe physical and mental deficits. Short- and long-term rehabilitation of patients with TBI provides a means towards recovery from these injuries. Rehabilitation techniques range from traditional physical and speech therapy to visual-motor coordination activities and group social activities.[2] Just as physical rehabilitation in recent years has provided significant improvement in patient mobility, cognitive rehabilitation has become an important tool for retraining lifestyle behaviors.[3,4]

An important component of cognitive rehabilitation is visual-motor training. It has been shown to be useful in improving patient recovery. Various forms of visual-motor training have been investigated in recent years.[5] Gur and Ron performed a clinical trial where nine patients with hemilateral brain injury were assessed for improvements in smooth pursuit and optokinetic nystagmus following simple oculomotor training.[6] All patients in the experimental group exhibited improved responses and decreased recovery time as compared to the control group. Kerkhoff and Stogerer conducted a clinical study on fusional convergence with three patients diagnosed as brain damaged.[7] In their single-subject baseline design, two patients exhibited a significant increase in their fusional ranges, while the third demonstrated a moderate increase following training. Ciuffreda, Kapoor and Han examined objectively in a case series the effects of oculomotor rehabilitation on basic versional ocular motility.[8] They found that the subjects manifested quantitative improvement in basic versional accuracy and reading ability. They concluded that there were positive effects from oculomotor rehabilitation. These results, as well as those from other studies, provide strong support for the continued use of cognitive-visual-motor therapy.[5]

Video-based training has been used as a means to engage younger patients to participate in rehabilitative treatment.[9] Motor vehicle-traffic-related TBI is highest among adolescents ages 15 to 19 years.[1] This age group is ideal for computer-aided cognitive rehabilitation, since they represent the demographic group that has the highest rate of computer usage (69.8%).[10] Thus, individuals within this age range are typically familiar with computer-based programs. Furthermore, the need for cognitive rehabilitation has been increasingly recognized as crucial for this demographic to treat the effects of a TBI injury. Indeed, Katz and Ashley noted that "it is not uncommon to see children with brain injuries worsen cognitively and behaviorally as they grow into the late adolescence and young adulthood, unless they receive cognitive rehabilitation therapy throughout their developmental years."[5]

In recent years, computerized video-based training programs have been extended to both adolescent and adult patients. With the use of programs such as Captain's Log®,[9,a] video-based training has become popular with rehabilitation clinics to provide a consistent as well as entertaining training aid for TBI patients.[11,12] When integrated

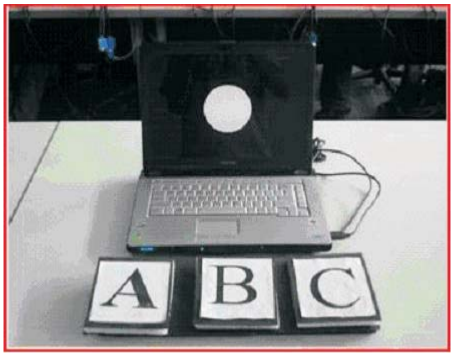

Figure 1. Laptop screen used to display the video-target training procedure. Patients were instructed to press the specific buttons in response to certain stimuli that appeared on the screen.

within the context of a broader program, cognitive rehabilitation has been shown to improve functional abilities.[3]

The aim of the current pilot study was to evaluate the effectiveness of experimental video-based training in TBI patients as a supplement to more conventional rehabilitation therapy. Response accuracy and eye-hand reaction time were used as quantitative measures of training effectiveness. In addition, the study sought to test if fatigue induced by sleep deprivation in normals could serve as a model for the cognitive deficits found in TBI patients.

METHODS

Apparatus

A specially designed keyboard with only three large functionally-relevant keys (A, B, C) was used for the TBI patients to input and facilitate their responses (Figure 1). It was developed around a standard keyboard as a base. The large buttons were constructed using three pieces of 6x4x0.5 inch Styrofoam®. The keyboard was stripped of all keys except these three reaction keys. The reaction keys were defined within the program as keys that would, for example, stop the timer, record the reaction time, or reset the timer. The bottom of each Styrofoam® button was attached to a reaction key using epoxy resin, and the assembly was reunited with the keyboard at the appropriate locations.

An HP DV9600 laptop computer was used to display the visual stimuli for the training procedures and for recording the responses. The program for driving the video display was coded in Matlab with the use of the Psychophysics Toolbox.[9,b] Each test challenged the patient's cognitive function in different areas such as critical thinking and memory. The program recorded the reaction time in seconds and response accuracy in percent.

Table 1. Description of Video Training Procedures

Test Name	Response Key Notation	Training Description	Instructions to Subject
Size Comparison	A- Left side B- Right Side	Two circles with different sizes are presented on the screen	Identify the bigger circle
Figure Identification	A- Shape B- Letter C- Number	Shape, letter or number is presented on the screen	Identify the type of figure on the screen
Three Figure Movement Identification	A- Shape B- Letter C- Number	Shape, letter or number is slowly displaced downward from the top of the screen; one of these images will be displayed to the right	Identify the figure that is displaced to the right
Location Matching	A- Left Answer B- Center Answer C- Right Answer	A room in a house will be displayed for 2 seconds, then will disappear, and then three objects will be presented	Identify which room the object belongs in
Occupational Matching	A- Left Answer B- Center Answer C- Right Answer	Image of a professional is displayed on the screen for 2 seconds, then will disappear, and then three vehicles will appear	Identify which vehicle the occupation uses
Monetary Matching	A- Left Answer B- Center Answer C- Right Answer	Three different combinations of coins are presented on the screen	Identify the coin amount that is equal to one dollar

The six test protocols were independently developed by the authors based on practical design considerations and key functional capabilities of these patients. Recommendations from attending clinicians were incorporated into the final design of the video based training procedures. Descriptions of each of the training procedures are shown in Table 1, and examples of video-based exercises are shown in Figure. 2.

The training procedures were structured so that they assessed a specific practical skill. The last three procedures were designed to test everyday life skills by engaging the subject to develop a "neuropsychological scaffold,"[1] allowing subjects to perform complex skills by breaking them down into their simpler components.

Facilities and Subjects

This study was approved by the Institution Review Board of Rutgers University and JFK Johnson Rehabilitation Institute. Subjects voluntarily consented to their participation in the study after having the consent form read to them by a team member.

The facility at John F. Kennedy (JFK) hospital in Edison, NJ maintains a long-term neurological recovery unit, the Hartwyck Rehabilitation Center. Patients, whose injury occurred three months to one year prior to the commencement of this project, and were neurologically stable, were included in the study.

Three TBI patients (two males and one female) ranging in age from 18 to 23 were tested as well as three normals (three males) all aged 21 years who served as controls (Table 2). The TBI patients were residents at the Hartwyck Rehabilitation Center in Edison, NJ, and the normal control subjects were students at Rutgers University, NJ.

Specific inclusion/exclusion criteria were used to select the patients and the control subjects. All participants had corrected visual acuity at distance of 20/30 or better. They were able to perform tasks requiring them to extend an arm and press a button on the keyboard. They were also able to remain attentive to the task for at least 10 minutes. All subjects were able to comprehend verbal or written instructions. No participants with significant dementia, psychosis or hemilateral visual field deficit were included. Patient diagnoses were obtained from the physicians records at the Hartwyck facility, and these are specified in Table 2.

Procedures

At least two members from the research group were present at all times during each test session. Patients were brought into an exercise room by an occupational therapist prior to the trials. Care was taken to

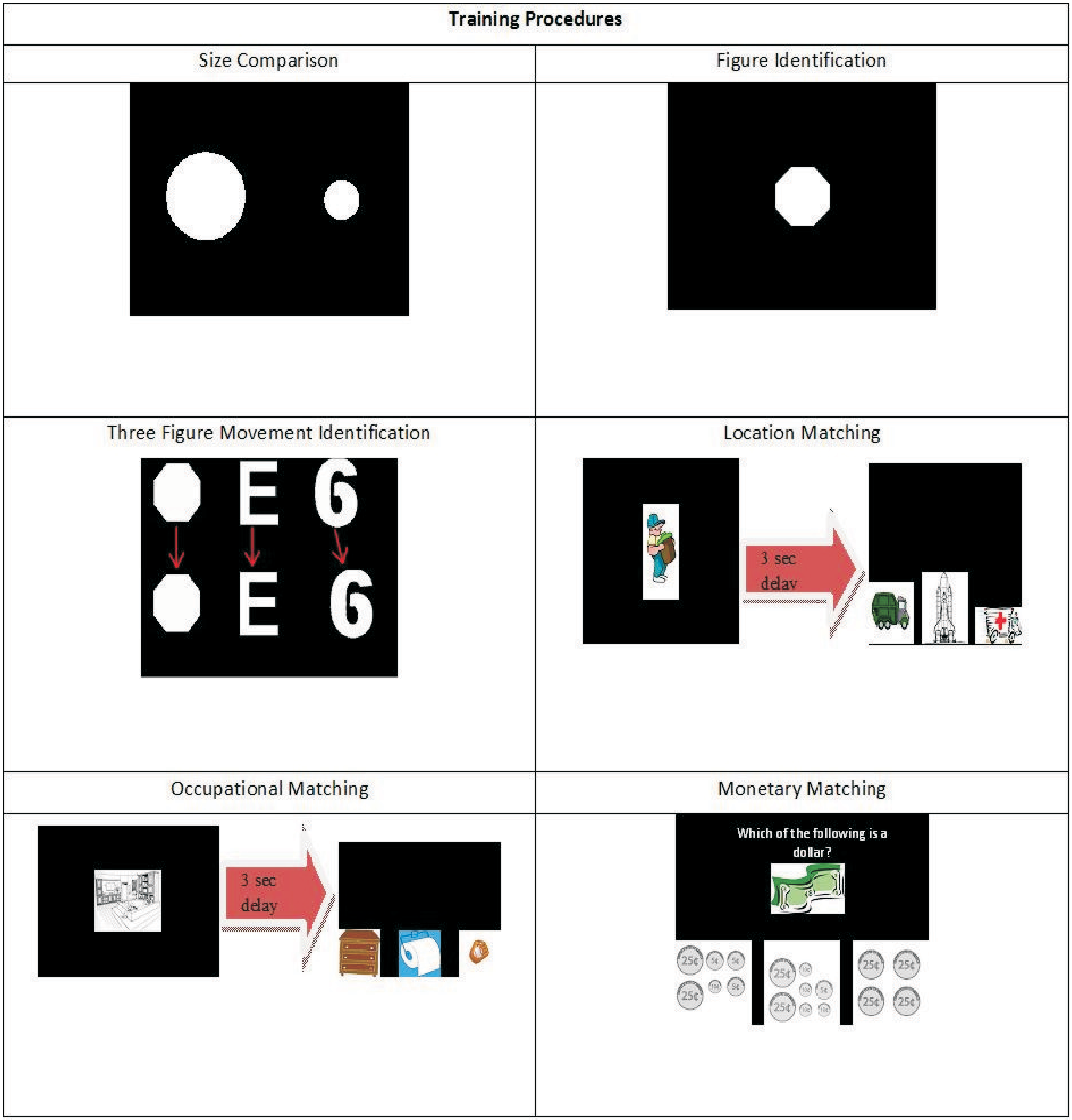

Figure 2. Examples of the video-based training procedures.

minimize external interference and ensure privacy during each session. The training procedures were as follows: patients were positioned in front of the laptop screen at a distance of 24". The keyboard was placed in front of the participant at a distance of 10" from the edge of the table. They were asked to maintain their hands on the table before reacting to the stimuli. This ensured response consistency among the patients. Six different identity procedures with 10 trials each were performed by each participant. (Table 1; Figure 2)

At the beginning of each procedure, the members of the group provided verbal instructions to the subject. During the course of the trials, no specific feedback was provided to the patients. The average time taken by the patients was approximately 15 minutes per session.

The control group performed the same tests in a similar test setting at another location on the Rutgers University campus. The instructions were identical. The control subjects, like the patients, were isolated in the room to ensure no external interference and maintain privacy. The control group underwent additional sessions under a "fatigue" condition in an attempt to mimic a TBI cognitive deficit. This was accomplished by having the control subjects remain awake past their usual bedtime, until they were

Table 2. Patient Clinical Information

	Patient 1	Patient 2	Patient 3
Age (years)	18	23	19
Diagnosis	Craniotomy secondary to brain tumor and cerebro-vascular accident	Traumatic Brain Injury	Traumatic Brain Injury
Onset	Nov 2007	June 2009	Summer 2009
# of Injuries	1	1	1
Etiology	Had brain tumor and related surgery	Motor vehicle accident	Hit by car
Severity	Moderate to severe TBI	Moderate to severe TBI	Moderate to severe TBI

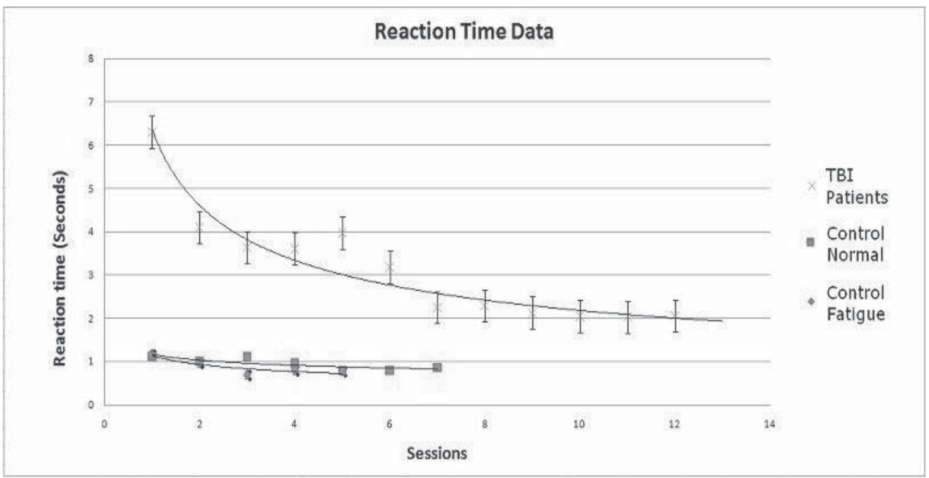

Figure 3 – Reaction times for patients, normals, and normals under the fatigued condition. Error bars represent +/- 1 s.e.m.

subjectively fatigued.[13] Typically, the control subjects stayed awake about 3 hours past their normal bedtimes.

In the experimental trials, upon obtaining the response, a point was given only if the response was correct. The reaction time for that trial was recorded. For each trial and procedure, an accuracy score was obtained by dividing the number of points obtained by 10. In addition, for each experimental session, the average group reaction time was obtained for each of the procedures. A composite reaction time was calculated by taking the mean of the average reaction times across all procedures across subjects.

RESULTS

Typical results for accuracy for both control subjects and TBI patients ranged from 90-100% correct for each of the procedures. The group mean reaction time results for all six tests are shown in Figure 3.

The TBI patients exhibited an exponential decline in the composite reaction time across the experimental sessions. In general, the patients started with an elevated reaction time in the first session. With each progressive session, the reaction time continued to decrease, until an asymptotic (approaching a given value as an expression containing a variable tends to infinity) level was attained. For the control subjects under the normal condition, the mean reaction time retained a relatively level trend throughout the sessions, and thus no significant decrease was evident. The fatigue condition for the normal subjects did not differ significantly from the non-fatigue normal data (Table 3). However, both normal non-fatigued and fatigued reaction times were significantly lower than the patient data (t-test, $p < 0.01$).

DISCUSSION

Cognitive rehabilitation has been demonstrated to be an important component of recovery in TBI patients.[12] Video-based tests engage the patients by invoking their reasoning ability.[14] The training procedures incorporated two basic elements, object recognition and mental arithmetic. These challenged the patients' cognitive functions. The continued decrease in group mean reaction time in the TBI patients as training progressed suggested improved concentration in cognition and reasoning, as well as perhaps improved motor responsivity.[5] However, the patient's reaction times were always significantly elevated when compared with the controls.

Normal subjects under the fatigue condition did not exhibit any significant increase in group mean reaction time. This suggested that the fatigue condition did not provide a good model for the reduced and slowed cognitive and visual motor functions in the brain injury patients. This also suggested that response time in the fatigue control group was affected by a different mechanism than in the brain injury patients. This could be attributed to the extra cognitive processing time needed by the patients, even after extensive training sessions. There appears to remain a significant gap in brain processing capability between normals and TBI patients. The TBI condition appears to cause a dysfunction in the neural centers for cognitive function. The role of rehabilitation should be to relearn these simple tasks and build on the neurological scaffolding. The rehabilitation for brain injury does not apparently restore functionality to pre-brain injured levels, but instead constructs a new level of functionality.[15] On the other hand, as this was a relatively short-term study, with continued training, this barrier in reduction of reaction time might be overcome. Patients could possibley exhibit a further reduction in reaction time.

Despite the fact that patient reaction times were elevated relative to the control subjects, accuracy was still maintained among the patients. This shows that, although various areas in the brain were damaged, patients were still able to reason and perform mental arithmetic accurately, albeit with a neurological delay.

Inclusion of more video cognitive decision-making elements is suggested to challenge further the patient's reasoning faculties. Research needs to be conducted with clinical trials to more effectively challenge attention and reasoning abilities of TBI patients in a larger sample population. Adding elements that force the patients to be attentive for longer periods of times may also help improve their cognitive skill. Since accuracy in the TBI patients was above 80% in this study,

Table 3. Statistical Comparisons of Patient and Normal Data

	p-values
TBI data vs Normal Nonfatigue data	<.01
TBI data vs Normal Fatigue data	<.01
Normal data vs Normal Fatigue data	.52

newer and more demanding training protocols should be designed to test the limits of their memory-based reasoning skills. Video-based training procedures, incorporating elements of logic, memory, attentiveness, composure, and judgment should also be investigated. Studies where procedures evoke higher-level social attitudes in various situational settings are suggested in the future.

Conclusion

The study showed that TBI patients improved exponentially in their attention as the sessions progressed. The procedures emphasized abstract and logical reasoning and were especially helpful in improving attention over the course of the study. However, there was a lower limit to the patients' group mean reaction time, which was still above the level for normals. This could be possibly be attributed to the TBI.". Additionally, it was also found that the accuracy remained relatively high among TBI patients, suggesting that other than the increased processing time, the injury did not impair their ability to perform the exercises.

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Note

The authors have no proprietary interest in any of the equipment used in this study.

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