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NEUROPSYCHOLOGICAL REHABILITATION OF PATIENTS WITH TRAUMATIC BRAIN INJURY

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SUMMARY

Background: The subject literature supports that patients with Traumatic Brain Injury (TBI) have a reduction in information processing speed and that this may contribute to deficits in attention, orientation and executive functioning including a deficit in mental flexibility, planning, self-monitoring, and problem solving. Therefore the aim of the present study was to remediate neuropsychological deficits of patients with TBI through neuropsychological rehabilitation.

Material/ Methods: Based upon a purposive sampling technique 10 patients with TBI falling within the age range of 20-40 years and fulfilling the inclusion and exclusion criteria were chosen from the All India Institute of Speech and Hearing, Mysuru, India. These patients were assessed on the Luria Nebraska Neuropsychological Battery for Adults. Based upon patient convenience, they were divided equally into an experimental and control group. Patients in the experimental group were given neuropsychological rehabilitation for 6 months. Brainwave-R and Talking Pen ware used as a rehabilitative tool.

Results: The results reveal that patients with TBI have significant neuropsychological deficits related to verbal, visual & working memory, visuo-spatial organization, arithmetic, spelling, writing, fine motor coordination and executive functioning. Also, neuropsychological rehabilitation was found effective in remediating these deficits but no significant improvement was found in motor writing skills and complex verbal arithmetic.

Conclusions: Neuropsychological rehabilitation is effective in the rehabilitating of cognitive deficits in patients with TBI.

Keywords: Trauma, Brain, Neuropsychological deficits, Cognitive Rehabilitation, Luria Nebraska Neuropsychological Battery-A, The Talking Pen, Brainwave-R

INTRODUCTION

TBI is the term used to refer to all the brain injuries caused by the impact of an external force e.g. falls, vehicle accidents, and violence etc. The Brain Injury Association of America (2011), defines TBI as an alteration in brain function, or other evidence of brain pathology, caused by an external force. It is the most common cause of death and disability in young people and survivors often suffer from various physical, motor, sensory, psychiatric and cognitive deficits.

The rehabilitation of TBI is a complex process for which a well-integrated, multidisciplinary, patient-oriented team is needed. Before, the 1970s only physical rehabilitation was given importance in rehabilitation phases. Later, it was recognized that residual behavioural, sensorimotor and cognitive impairment were the fundamental obstacle to readjustment following TBI. It was observed that even if the patients were able to reach their pre-morbid physical state, their performance at home and work was markedly affected. It was soon realized that neuropsychological impairments were the major barrier to the vocational, emotional and interpersonal functioning for many individuals affected by TBI. Not simply the patient but also the family members of TBI survivors were affected by their marked neuropsychological impairment, because the family members had to grapple daily with the victims poor judgment, forgetfulness and limited concentration span, which are frequent problems following TBI. Thus the need for neuropsychological rehabilitation (NR) was felt.

NR is a treatment modality employed by a neuropsychologist to assist patients who have sustained cognitive, emotional, sensorimotor and behavioral impairments as the result of acquired brain injury. Rehabilitation of the sensorimotor and cognitive function typically involves methods for retraining the neural pathways or training new neural pathways to regain or improve the neurocognitive functioning that has been diminished by disease or traumatic injury. The remediation of cognitive impairments is one of the main focuses of NR. This remediation is achieved through cognitive rehabilitation (CR) also known as cognitive rehabilitation therapy (CRT). The treatment chosen for a TBI can be either modular or comprehensive in nature. In modular models of CRT, treatments are generally aimed at a single cognitive impairment, such as memory (memory remediation) or language (aphasia therapy). In contrast, patients with multiple impairments (i.e., deficits in attention and memory, along with impulsivity and depression) may receive a comprehensive programme also referred to as “holistic”, “multi-modal”, or “neuropsychological rehabilitation”.

Various comprehensive and well controlled studies have investigated the effectiveness of NR. Comprehensive-holistic CR involving a multidisciplinary approach along with home based intervention, individual education and encouragement have been found effective for TBI survivors and in 90% of cases is successful in helping TBI survivors to return to their job and provide efficient community reintegration (Salazar et al., 2000; Warden et al., 2000). In a meta-analysis (Chestnut et al.,1999) evidence was found supporting the effectiveness of CR for persons

with TBI. They found that specific forms of CR reduce memory failures and anxiety, and improve the self-concept and interpersonal relationships for persons with TBI. Similarly, an NIH sponsored consensus development panel on the rehabilitation of persons with TBI identified studies that showed improvements in specific cognitive processes (National Institutes of Health, 1999). Improvements were found in attention, memory and executive functions, and in some cases involved the use of compensatory aids (such as memory books), but the drawback of the study was that it involved interdisciplinary rehabilitation programmes, making it difficult to evaluate the effectiveness of specific CR programs. The current study was thus proposed to study the effectiveness of the paper pencil techniques of neuropsychological rehabilitation on patients with TBI in an Indian setting.

Aim: To study the impact of neuropsychological rehabilitation on the neuropsychological deficits of patients with TBI.

MATERIALS AND METHODS

Sample

Based upon a purposive sampling technique, 10 right handed patients with open/closed head injury, aged 20-40 years, of either sex, with a significant neuropsychological deficit and with a minimum gap of 1 year after injury, having as a minimum secondary education and with English as the medium of instruction were chosen from All India Institute of Speech & Hearing (AIISH), Mysuru, India. Patients with mild brain injury, with any co-morbid psychiatric condition, with a history of substance dependence, with severe behavioral problems and with impairment in expressive speech, hearing, vision or physical amputation after injury were excluded from the study. Patients under medication pertaining to brain injury were also excluded from the study. The informed consent of the patient and guardian was taken before the intervention process. Based upon patient convenience they were divided into an experimental and control group. Patients in the control group were wait listed and were called for therapy after 6 months of research completion. The human data included in this study was obtained in compliance with the Helsinki declaration.

Tools

(1) **Socio-Demographic and Clinical Data Sheet:** A semi-structured form was prepared for the study covering all areas of socio-demographic details like age, sex, domicile, education, employment, marital status etc., and questions related to co-morbid psychiatric disorders, hearing or visual impairment or severe physical illness in the recent past.

(2) **Handedness Scale (Annet, 1970):** Based on this scale the dominant hemisphere is ascertained. It has 5 items. The subjects are asked to indicate their preference of hand in certain daily activity tasks.

(3) **Brief Psychiatric Rating Scale (BPRS: Overall & Gorham, 1962):** This is an 18-item scale measuring positive symptoms, general psychopathology and affective symptoms. Each item is rated on a 7-point rating scale and accordingly the severity of psychopathology is ascertained. Ratings up till 3 indicate the non-pathological intensity of symptoms and 4-7 indicates the pathological severity of symptoms.

(4) **Head Injury Behaviour Scale (HIBS: Smith & Godfrey, 1995):** This is a 4 point rating scale which assesses the behavioural excesses and behavioural deficits after brain injury. It is both a self administered rating scale as well as one to be administered by family members or relatives.

(5) **Glasgow Coma scale (GCS: Teasdale, 1974):** This test is used to assess the severity of TBI. It assess the performance of the patient in three areas i.e. eye opening, best motor response and verbal response. The minimum response of the scale is 3 and the maximum response is 15. A score of 8 or less indicates severe head injury, scores of 9-12 indicate moderate brain injury and 12-15 indicate mild head injury.

(6) **Luria Nebraska Neuropsychological Battery Adults- Form I (LNNB-A: Golden, 1981):** The battery, developed in 1981 by Charles Golden, is appropriate for people aged 13 and older; it consists of 269 items in 11 clinical scales (Motor (c1), Rhythm (c2), Tactile (c3), Visual (c4), Receptive Speech (c5), Expressive Speech (c6), Writing (c7), Reading (c8), Arithmetic (c9), Memory (c10) & Intelligence (c11)). The original test has been extended to elicit specific neuropsychological deficits using factor analysis, called factor scales. A total of 28 factor scales have been identified from 11 clinical scales.

(7) **Brainwave-R**: **Cognitive Strategies and Techniques for Brain Injury Rehabilitation (Malia et al., 2002):** This series has been designed to assist in the cognitive rehabilitation of individuals with brain injuries. It consists of a large array of exercises (mainly pen and paper based), which are organized into five modules i.e. attention, visual processing, information processing, memory & executive functions. The five Brainwave-R modules are hierarchically presented according to Luria's (1963) theory of brain function, which suggested that complex behavioral processes are distributed throughout the brain in functional systems. The purpose of each module can be summarized as follows:

1. Attention – This module aims to develop focused, sustained, selective and alternating attention skills in order to optimize arousal and alertness levels.
2. Visual Processing – This module aims to develop more accurate saccadic eye movements, visual scanning skills, visual attention, figure-ground discrimination, pattern recognition, visual memory and the ability to mentally manipulate visual information. It also reinforces the exercises on attention completed in the previous module.
3. Information Processing – This module is divided into two sections. Part 1 aims to develop ordered, sequenced thinking skills. Part 2 aims to develop

the ability to work more quickly, under time constraints and with more complex information.

4. Memory – This module has been designed to teach the client about memory processes and emphasizes the use of strategies to compensate for memory problems.
5. Executive Functions – This module also has been divided into two sections. Part 1 teaches the client about the executive functions and strategies that can be used to compensate for deficits in this area. Part 2 provides a choice of projects for the client to organize, plan and execute using the strategies taught in Part 1.

(8) **The Talking Pen (Talking Pen: Wayne Engineering, 1974):** Talking Pen is an instrument for developing fine-motor skills through pattern tracing. It is most often used to diagnose and develop gross and fine motor skills, hand-eye coordination, laterality, directionality, auditory perception, form perception, ocular pursuits and spatial relationships.

Research Design

A quasi-experimental design i.e. Non-equivalent Control group design was chosen for the study.

Procedure

Patients with TBI were identified from AIISH OPD and were initially screened using socio-demographic data sheet, Handedness scale, BPRS, GCS & HIBS. Patients fulfilling the inclusion and exclusion criteria were assessed on LNNB-A. Once the pretest was conducted and significant neuropsychological deficits were found in the patients, they were either allotted to the experimental group or the control group. This division was based upon patient convenience , those patients who came from distant places or had any major family issues and therefore rejected participation in the 6-months programme were kept in the control group and those who were ready to attend therapy regularly were chosen for the experimental group. Patients were explained the relevance and need of the study and were asked to sign the consent form (the entire research was completed in accordance with the Helsinki declaration). Therapy was carried out on an individual basis for six months. Target areas and the number of therapy sessions varied with every month. A co-therapist from among the family member was also chosen who could guide the patient in carrying out homeworks at home. Various intervention strategies were used from Brainwave-R and talking pen to remediate the patients' neuropsychological deficits. The process involved in therapy is described below:

1st Month: Target areas: Attention, Visual Processing & Fine Motor Co-ordination activities introduced.

Therapy sessions: 45-minute Session for 5 Days in the week with homework's For Remaining 2 Days.

2nd Month: **Target areas:** Memory training introduced (Revision of Attention, Visual Processing & Fine Motor Co-ordination activities).

Therapy sessions: 45-minute session for 4 days in the week with homeworks for the remaining 3 days.

3rd Month: **Target areas:** Information Processing Activities introduced (Revision of memory & fine motor co-ordination activities)

Therapy sessions: 45-minute session for 3 days in a week with homeworks for the remaining 4 days.

4th Month: **Target areas:** Executive Functioning activities introduced (Revision of information processing and fine motor co-ordination activities)

Therapy sessions: 45-minute session for 3 days in a week with homeworks for the remaining 4 days.

5th Month: **Target areas:** Revision of information processing and executive functioning activities.

Therapy sessions: 45-minute session for 2 days in the week with homeworks for the remaining 5 days.

6th Month: Target areas: Revision of executive functioning activities. (Patient's participation in community activity encouraged)

Therapy sessions: 45-minute session for 1 day in the week with homeworks for the remaining 6 days

RESULTS

The results of the study are discussed below.

Table 1 highlights the clinical profile of patients with TBI. It was found that all the patients chosen for the study had closed head injury which had resulted from road traffic accident and all of them had moderate to severe brain injury (score falling between 3-11). None of the patients had any psychotic symptom (score of 3 and below) and all the patients had mild behavioral problems subsequent to TBI (score less than 20). This behaviour problem was not significant enough to effect the therapeutic procedures. Thus, all the patients were similar in their clinical profile. The table also highlights the localization and lateralization of the lesion incurred by TBI patients, as deciphered through functional (LNNB-A). Through functional analysis it was found that most of the patients had bilateral lesions and incidentally in all the patients' the parietal lobe had a lesion along with some other cortical region lesions. Although, no deliberate attempt was made to match patients in terms of the lesion incurred but similarity observed in above two areas have increased the prospects of knowing the exact scope NR. This result has also given an additional benefit in terms of the management of these patients, as patients with a similar type of lesion may have a similar type of deficit.

On LNNB-A, based upon the age and education level of each patient a 'critical level' was calculated, this acts as the cut off score for the patient. All the scores above this critical level are deficit areas and scores which lie below it are areas which are intact.

Table 2 elaborates the percentage of patients with TBI above and below the critical level on the clinical scale. If we analyze the table it is found that patients have more problems in motor (c1), visual (c4) expressive (c6), writing (c7), reading (c8), memory (c9), arithmetic (c10) and intelligence scales (c11). No major deficit was observed in the rhythm (c2), tactile (c3) and receptive (c5) subscale.

Table 1. Clinical Profile of the Patients

Pt's	Time Since Accident (years)	Type Of Injury	Scores				
			LNNB-A	Glasgow Coma Scale	Brief Psychiatric Rating Scale	Head Injury Behaviour Scale	
						Guardian's Rating	Patient's Rating
P1	2	closed	Bilateral parieto-occipital lesion.	5	1	15	18
P2	1	closed	Bilateral parieto-occipito-temporal lesion.	9	0	10	15
P3	2.5	closed	Bilateral temporo-parieto-occipital lesion.	8	0	14	15
P4	1.2	closed	Bilateral sensorimotor (fronto-parietal) lesion.	7	0	12	12
P5	5	closed	Left sensorimotor (fronto-parietal) lesion.	9	1	18	19
P6	1.6	closed	Bilateral parieto-occipito-temporal lesion.	8	2	7	10
P7	3	closed	Bilateral parieto-occipito-temporal lesion.	6	1	17	18
P8	2	closed	Bilateral parieto-occipito-frontal lesion	10	3	5	8
P9	1.6	closed	Bilateral parieto-occipito-frontal lesion	9	0	13	15
P10	1.6	closed	Bilateral fronto-parieto-occipital lesion,	6	2	11	14

Table 2. Percentage of TBI Survivors with Major Deficits in Clinical Scale

S. No	Clinical Scales	Percentage of Patient Below Critical Level	Percentage of Patient Above Critical Level
1.	Motor Scale (c1)	60%	40%
2.	Rhythm Scale (c2)	100%	---
3.	Tactile Scale (c3)	90%	10%
4.	Visual Scale (c4)	20%	*80%*
5.	Receptive Scale (c5)	90%	10%
6.	Expressive Scale (c6)	40%	*60%*
7.	Writing Scale (c7)	40%	*60%*
8.	Reading Scale (c8)	40%	*60%*
9.	Arithmetic Scale (c9)	20%	*80%*
10.	Memory Scale (c10)	20%	*80%*
11.	Intelligence Scale (c11)	30%	*70%*

Table 3. Percentage of TBI Survivors with Major Deficits in Factor Scale

S. No	Factor Scales	Percentage of Patient Below Critical Level	Percentage of Patient Above Critical Level
1.	Kinesthetic Based Movement (M1)	80 %	20%
2.	Drawing Speed (M2)	70%	30%
3.	Fine Motor Speed (M3)	20%	*80%*
4.	Spatial Based Movement (M4)	90%	10%
5.	Oral Motor Skills (M5)	80%	20%
6.	Rhythm and Pitch Perception (RH1)	100%	---
7.	Simple Tactile Sensation (T1)	80%	20%
8.	Stereognosis (T2)	90%	10%
9.	Visual acuity & Naming (V1)	30%	*70 %*
10.	Visual-Spatial Organization (V2)	30%	*70%*
11.	Phonemic Discrimination (R1)	100%	---
12.	Relational Concepts (R2)	60%	40%
13.	Concept Recognition (R3)	90%	10%
14.	Verbal-Spatial Relationships (R4)	100%	---
15.	Simple Phonetic Reading (E1)	60%	40%
16.	Word Repetition (E2)	80%	20%
17.	Reading Pollysyllabic Words (E3)	50%	50%
18.	Reading Complex Material (RE1)	40%	*60%*
19.	Reading Simple Material (RE2)	60%	40%
20.	Spelling (W1)	30%	*70%*
21.	Motor Writing Skill (W2)	50%	*50%*
22.	Arithmetic Calculations (A1)	20%	*80%*
23.	Number Reading (A2)	60%	40%
24.	Verbal Memory (ME1)	10%	*90%*
25.	Visual & Complex Memory (ME2)	20%	*80%*
26.	General Verbal Intelligence (I1)	80%	20%
27.	Complex Verbal Arithmetic (I2)	10%	*90%*
28.	Simple Verbal Arithmetic (I3)	30%	*70%*

Table 3 highlights the percentage of patients with TBI above and below the critical level on the factor scale. Results reveal that TBI survivors had difficulty in fine motor speed, visual acuity and naming, visual spatial organization, reading complex material and spelling, verbal memory, complex and visual memory, simple and complex arithmetic. The results also reveal that most of the patients had intact kinesthetic based movement, drawing speed, spatial based movements, oral motor skills, tactile sensation and have no symptoms of stereognosis. Also, there was no deficit observed in phonemic discrimination, concept recognition, verbal spatial relations, word repetition, and reading simple and complex material. In arithmetic skills there was no deficit observed in reading numbers. Their general verbal intelligence was also intact.

Before analyzing the effect of NR on the experimental group it is important to compare the groups (Between Group Analysis) before the intervention. The results assessed by the Mann Whitney U test reveal that before the intervention the two groups were similar to each other on all the clinical scales (Table 4). Patients from both the groups had a similar type of deficit and were matched to each other. Subscale rhythm (c2), tactile (c3) and receptive (c5) are excluded from the table as there was no major deficit observed in these three subscales. Similarly, both the groups (Between Group Analysis) were compared on the fac-

tor scale; the comparison was made for those scales which were found to be impaired in patients. Out of 28 factors, 11 scales were mainly impaired in patients from both the groups. Therefore a comparison was made for only these 11 scales. The results (Table 4) revealed that before the intervention there was no significant difference between both the groups on all 11 scales.

Table 5 shows the result of 'Between Group Analysis' (Mann Whitney U test) conducted after the intervention, it highlights that there was significant improvement found on the visual scale, expressive speech, arithmetic, memory and intelligence scale but there was no statistical difference found in the reading, writing and motor scale. Similarly, 'between group analysis' of the factor scale reveals that after the intervention two groups were significantly different in visual-acuity and naming, arithmetic, verbal memory, visual and complex memory, and simple verbal arithmetic. However, there was no group difference found in fine motor speed, visual spatial organization, spelling, motor writing skills, the reading of complex material and complex arithmetic skills after intervention. It is thus evident through 'between group analyses' that after the intervention there was a significant group difference in some of the major areas chosen for the intervention.

To gain a clear understanding of the impact of NR on TBI survivors, 'within-group analysis' was carried out using the Wilcoxon Sign Rank Test i.e. each patient was compared before and after the intervention on each subscale. Table 6 highlights the pretest and posttest raw score of each patient of the experimental group on clinical scales along with their mean rank, z-score and p-value. The re-

Table 4. Between Group Analysis of Clinical & Factor Scales at Baseline

S. No	Areas Of Assessment (Clinical Scale)	Experimental Group- Pre Test Mean Rank	Control Group- Pre Test Mean Rank	Mann Whitney U Test (Z-Score)
1.	Motor (C1)	5.60	5.40	0.104 (NS)
2.	Visual (C4)	6.40	4.60	0.949 (NS)
3.	Expressive (C6)	4.40	6.60	1.149 (NS)
4.	Writing (C7)	5.70	5.30	0.210 (NS)
5.	Reading (C8)	4.70	6.30	0.838 (NS)
6.	Arithmetic (C9)	4.40	6.60	1.149 (NS)
7.	Memory (C10)	6.30	4.70	0.838 (NS)
8.	Intelligence (C11)	5.40	5.60	0.105 (NS)
	FACTOR SCALES			
1.	Fine Motor Speed	5.60	5.40	0.105 (NS)
2.	Visual Acuity And Naming	5.90	5.10	0.424 (NS)
3.	Visual Spatial Organization	7.10	3.90	1.708 (NS)
4.	Reading Complex Material	4.90	6.10	0.629 (NS)
5.	Spelling	5.50	5.50	.000 (NS)
6.	Motor Writing Skill	6.00	5.00	.655 (NS)
7.	Arithmetic	5.50	6.50	1.048 (NS)
8.	Verbal Memory	6.00	5.00	0.541 (NS)
9.	Visual And Complex Memory	6.40	4.60	0.955 (NS)
10.	Complex Verbal Arithmetic	5.80	5.20	0.386 (NS)
11.	Simple Verbal Arithmetic	4.80	6.20	0.757 (NS)

NS: Non significant

Table 5. Between Group Analysis of Clinical & Factor Scales at Post Assessment

S. No	Areas Of Assessment (Clinical Scale)	Experimental Group- Post Test Mean Rank	Control Group- Post Test Mean Rank	Mann Whitney U Test (Z-Score)
1.	Motor (C1)	4.10	6.90	1.471 (NS)
2.	Visual (C4)	3.10	7.90	2.522 **
3.	Expressive (C6)	3.40	7.60	2.207 *
4.	Writing (C7)	4.20	6.80	1.383(NS)
5.	Reading (C8)	3.80	7.20	1.803 (NS)
6.	Arithmetic (C9)	3.00	8.00	2.619**
7.	Memory (C10)	3.00	8.00	2.635**
8.	Intelligence C11)	3.00	8.00	2.611**
FACTOR SCALE				
1.	Fine Motor Speed	4.10	6.90	1.490 (NS)
2.	Visual Acuity And Naming	3.60	7.40	2.124*
3.	Visual Spatial Organization	4.60	6.40	1.017 (NS)
4.	Reading Complex Material	3.80	7.20	1.809 (NS)
5.	Spelling	4.00	7.00	1.576 (NS)
6.	Motor Writing Skill	6.00	5.00	1.000 (NS)
7.	Arithmetic	3.20	7.80	2.432 **
8.	Verbal Memory	3.00	8.00	2.652 **
9.	Visual And Complex Memory	3.70	7.30	1.959 *
10.	Complex Verbal Arithmetic	4.40	6.60	1.226 (NS)
11.	Simple Verbal Arithmetic	3.50	7.50	2.352*

*p<.05; **p<.01 level of significance; NS: Non significant

Table 6. Within Group Comparison of Experimental Group on Clinical Scale

Areas of Assessment (Clinical Scale)		Experimental Group					Wilcoxon Sign Rank Test	
		P1	P2	P3	P4	P5	Mean Rank	Z-score
Motor Scale (C1)	Pre Test	33	24	5	7	11	3.00	2.023*
	Post Test	10	4	1	1	3		
Visual Scale (C4)	Pre Test	14	16	16	13	21	3.00	2.032*
	Post Test	3	5	4	4	6		
Expressive Speech (C6)	Pre Test	7	27	18	3	23	3.00	2.032 *
	Post Test	1	14	5	1	6		
Writing (C7)	Pre Test	9	10	4	7	20	3.00	2.032*
	Post Test	5	4	1	2	8		
Reading (C8)	Pre Test	3	11	1	2	12	3.00	2.032*
	Post Test	1	4	0	0	4		
Arithmetic (C9)	Pre Test	6	13	4	2	19	3.00	2.023*
	Post Test	1	5	1	0	2		
Memory (C10)	Pre Test	18	21	13	25	11	3.00	2.032*
	Post Test	4	7	2	8	4		
Intelligence (C11)	Pre Test	26	32	32	6	23	3.00	2.032*
	Post Test	11	13	8	1	12		

*p<.05; **p<.01 level of significance

sults reveal that after the intervention there was significant improvement found in patients of the experimental group for all the deficit areas. The results highlight the importance of intervention through which there was significant improvement found in the experimental group.

Table 7 reveals the scores of the control group on clinical scales which was deciphered through the 'Wilcoxon Sign Rank' test. The results highlight that only in subscale expressive speech was a significant level of improvement found, one

Table 7. Within Group Comparison of Control Group on Clinical Scale

Areas of Assessment (Clinical Scale)		Control Group					Wilcoxon Sign Rank Test	
		P6	P7	P8	P9	P10	Mean Rank	Z-score
Motor Scale (C1)	Pre Test	4	2	42	16	29	2.50	1.826 (NS)
	Post Test	3	2	36	11	21		
Visual Scale (C4)	Pre Test	12	17	8	17	8	3.50	1.131 (NS)
	Post Test	10	15	6	16	10		
Expressive Speech (C6)	Pre Test	13	25	47	28	14	3.00	2.023*
	Post Test	8	16	28	18	8		
Writing (C7)	Pre Test	5	12	17	6	7	2.50	1.857 (NS)
	Post Test	4	9	14	5	7		
Reading (C8)	Pre Test	0	14	15	11	6	2.00	1.633 (NS)
	Post Test	0	10	12	8	6		
Arithmetic (C9)	Pre Test	7	10	24	15	11	2.50	1.000 (NS)
	Post Test	6	11	23	15	10		
Memory (C10)	Pre Test	19	12	18	10	16	4.50	.828 (NS)
	Post Test	18	10	20	9	15		
Intelligence (C11)	Pre Test	17	34.	31	30	22	3.67	.966 (NS)
	Post Test	15	35	29	31	21		

*p<.05; NS: Non Significant

Table 8. Within Group Comparison of Experimental Group on Factor Scale

Areas of Assessment (Factor Scale)		Experimental Group					Wilcoxon Sign Rank Test	
		P1	P2	P3	P4	P5	Mean Rank	Z-score
Fine Motor Speed	Pre Test	13	8	5	7	5	3.00	2.032*
	Post Test	7	1	1	1	0		
Visual Acuity And Naming	Pre Test	5	7	6	6	8	3.00	2.041*
	Post Test	1	2	2	1	2		
Visual Spatial Organization	Pre Test	4	4	5	3	5	3.00	2.070*
	Post Test	0	0	1	0	2		
Reading Complex Material	Pre Test	3	8	1	2	10	3.00	2.032*
	Post Test	1	4	0	0	4		
Spelling	Pre Test	9	10	4	5	18	3.00	2.032*
	Post Test	3	4	1	0	9		
Motor Writing Skill	Pre Test	0	0	0	2	2	1.50	1.342 (NS)
	Post Test	0	0	0	1	0		
Arithmetic	Pre Test	6	13	4	0	16	3.50	1.826*
	Post Test	2	6	1	0	6		
Verbal Memory	Pre Test	5	10	7	9	6	3.50	1.761*
	Post Test	0	2	1	3	2		
Visual And Complex Memory	Pre Test	8	7	5	8	1	3.50	1.753*
	Post Test	2	3	2	3	2		
Complex Verbal Arithmetic	Pre Test	12	12	12	2	12	2.00	1.604 (NS)
	Post Test	0	10	2	1	8		
Simple Verbal Arithmetic	Pre Test	2	4	4	0	4	2.50	1.809*
	Post Test	0	0	0	0	0		

*p<.05; NS: Non Significant

Table 9. Within Group Comparison of Control Group on Factor Scale

Areas of Assessment (Factor Scale)		Control Group					Wilcoxon Sign Rank Test	
		P6	P7	P8	P9	P10	Mean Rank	Z-score
Fine Motor Speed	Pre Test	1	2	11	11	9	1.00	1.000 (NS)
	Post Test	0	2	11	10	9		
Visual Acuity And Naming	Pre Test	6	11	2	7	4	2.00	1.633 (NS)
	Post Test	3	10	2	5	3		
Visual Spatial Organization	Pre Test	3	2	2	5	0	1.75	0.272 (NS)
	Post Test	2	0	2	4	0		
Reading Complex Material	Pre Test	0	9	12	8	6	1.00	1.000 (NS)
	Post Test	0	8	12	8	6		
Spelling	Pre Test	7	12	17	4	7	2.75	.948 (NS)
	Post Test	4	10	12	3	5		
Motor Writing Skill	Pre Test	0	0	0	2	0	1.50	1.342 (NS)
	Post Test	0	0	0	0	0		
Arithmetic	Pre Test	10	8	16	15	11	2.50	0.680 (NS)
	Post Test	7	6	14	12	8		
Verbal Memory	Pre Test	8	6	7	6	6	1.50	0.000 (NS)
	Post Test	8	6	5	6	6		
Visual And Complex Memory	Pre Test	6	4	6	2	6	.00	1.000 (NS)
	Post Test	4	4	6	2	6		
Complex Verbal Arithmetic	Pre Test	12	12	12	8	10	.00	1.000 (NS)
	Post Test	11	12	10	8	10		
Simple Verbal Arithmetic	Pre Test	3	8	10	0	4	2.00	0.447 (NS)
	Post Test	2	8	6	0	4		

NS: Non significant

without any sort of intervention. In all the other areas there was no significant difference found in the pretest and post-test scores .

Similarly, in the factor scales (Table 8) it was found that after NR there was a significant improvement found in patients of the experimental group in deficit areas such as fine motor coordination, visual-acuity & naming, visuo-spatial organization, reading complex material, spelling, arithmetic, verbal memory, visual and complex memory and simple verbal arithmetic. However, there was no significant improvement found in motor writing skills & complex verbal arithmetic.

Table 9 highlights the scores of the control group on the factor scales and the results reveal that in all the subscales there was no significant difference in the pretest and post-test scores of patients in any of the scales.

DISCUSSION

The results reveal that almost all the patients with TBI had deficits in memory, visual processing, arithmetic skills and intellectual ability. Memory was found to be profoundly affected from amongst all the cognitive areas in patients with TBI. Patients were found to have deficits in verbal memory for both immediate and delayed recall. In addition to verbal memory, visual memory was also found to be impaired in patients with TBI. This result is consistent with the findings of Hoofien et al. (2001) & Colantonio et al. (2004) who found that deficits in verbal

memory persist for years after injury. Miotto et al. (2010) also found that patients with mild to moderate TBI have deficits in verbal memory, visuo-spatial recall and episodic recognition deficits. The memory of these patients is more impaired because of their poor associational ability and their inability to retain information when interfered by a situation or event, these problems leads to their inability to learn new information. This is consistent with the findings of Tate et al. (1991) who evaluated 87 patients with moderate to severe patients with TBI 6 months after their injury and found that 56% of survivors had difficulty in learning and memory than was the case in the controls.

Along with visual memory deficit there were deficits pertaining to visuo-spatial planning and organization. Patients with TBI were found to have poor visual acuity and naming. This is consistent with the findings of Vanderploeg et al. (2001) who reported that TBI survivors have deficit in visuo-spatial organization. In contrast to the above result, Miotto et al. (2010) found that TBI survivor have intact visuo-perceptive and visuo-spatial functions. This inconsistency is due to the fact that in the present study most of the patients had a parietal lobe lesion and the parietal lobe is directly involved in visuo-spatial organization.

Patients with TBI also reported deficits in functional intelligence. Deficits in functional intelligence indicate patients' inability to understand logical relationship, form analogies, poor reasoning and poor concept formation. An inability to interpret stories, proverbs and expressions indicates poor abstract thinking of the patients. These deficits can lead to poor problem solving and decision making. This deficit in functional intelligence contributes to deficits in executive functioning. Seidenberg et al. (1983) also found that neuropsychological measures requiring conceptual problem-solving ability, mental efficiency, and language-related skills are strongly related to IQ, while simple motor, constructional, and perceptual tasks are not. He further added that those functions which are considered as "higher level" executive functions like verbal and non-verbal reasoning, problem solving, and abstraction, are less related to psychometric intelligence (Seidenberg et al., 1983).

In arithmetic skills patients with TBI have intact reading, writing and simple calculation skills, however, complex arithmetic skills are significantly impaired in these patients. Deficits in arithmetic skill are directly related to a lesion in the parietal lobe. In the present study most of the patients reported deficits in arithmetic skills as the parietal lobe had a lesion in all the patients (Table 1). Another reason behind impairment in complex arithmetic skill is their impairment in logical thinking and reasoning. Complex arithmetic skills involve logical thinking and reasoning but patients with TBI have a functional intellectual deficit which leads to their poor problem solving. Also, poor arithmetic skills are the consequence of a poor working memory capacity, which involves retaining the information for a short span of time and manipulating the information. Mathematical competence entails a variety of complex skills that encompass conceptual content and procedures (e.g., arithmetic, algebra, and geometry); problem solving in these domains often involves the holding of partial information and the processing of new

information to arrive at a solution, which ought to require working memory resources. The association of working memory and arithmetic skills is supported by the review of Kimberly et al. (2010). Most of the patients also had difficulty in performing time bound calculations; this may be the result of the poor information processing capacity of these patients. This is consistent with the findings of Miotto et al. (2010) who found that 83% of patients chosen for the study had a poor information processing speed. In addition to working memory and information processing deficit, a problem in arithmetic skills is also the result of a poor visuo-spatial ability, which is directly involved in arithmetic activities such as lining up the numbers, borrowing and carrying numbers. Along with a deficit in arithmetic skills, patients have also difficulty in fluent reading, motor writing skills and spelling. It is generally assumed that this academic problem is observable in children with TBI. But the current study highlights that adults with TBI may also have a deficit in academic skills. Difficulty in reading complex material with fluency and poor spelling is the result of a deficit in understanding polysyllabic words. Miotto et al. (2010) in their study also reported verbal fluency as a major deficit in TBI survivors. These patients have no difficulty in understanding verbal spatial relationship or simple phonemes therefore simple reading is intact for these patients. Problems in writing skills is due to fine motor incoordination which is observable in 80% of cases in the present study.

The results also reveal that before the intervention phase there was no group difference between the experimental and control group, however, after the intervention there was significant group difference in the visual, expressive, arithmetic, memory and intelligence scale (Table 4 & 5). In the motor, reading and writing scales there was no difference seen at group level, however, in 'within group analysis', when each individual's pretest and post-test scores were compared, it was found that the experimental group patients had shown significant improvement in all the deficit areas in comparison to patients from the control group (Table 6 & 7).

Similarly, 'between group analyses' carried out for the factor scales show that there was no improvement in fine motor coordination, visuo-spatial organization, spelling and motor writing skills (Table 4 & 5); however, the results of 'within group analysis' on the factor scale show that there was a significant improvement found in all the major deficit areas (Table 8). This discrepancy in results is due to the small sample size of each group; therefore only extreme variation in the scores of both the groups brings a significant change in the group analysis. Through 'within group analysis' this lacuna is overcome as a patient's pretest and post-test scores are compared with each other and there it was highlighted that there was significant improvement in all the major deficit areas of patients with TBI.

The study thus indicates that there was significant improvement in all the major deficits of patients with TBI, therein indicating the efficacy of NR. It also indicates that the package used for the study is efficient in remediating the deficits of TBI survivors. The package used for the patients is based upon Luria's (1963) theory of brain function, which suggests that complex behavioral pro-

cesses are distributed throughout the brain in functional systems. He further states that each area of the central nervous system is involved in the brain-behavior relationship as being a part of one of three basic functions, labeled as units. The first unit consists of the brain stem and associated areas and control basic arousal and muscle tone. The second unit, includes posterior areas of the cortex, is integral in the reception, integration, and analysis of sensory information, receiving input from both internal and external stimuli. Executive functions such as planning, executing, and verifying behaviour and motor output are regulated by the third unit, the frontal and prefrontal areas of the brain. All the behaviours are the result of the interactions of these three units. Each unit is structured hierarchically, with primary, secondary, and tertiary zones. The current study satisfies the theory of Luria, as the techniques used for remediation were not targeted for any specific neuronal pathway rather they was based upon the functional systems i.e. attention (primary zone), information processing (secondary zone) and executive functioning (tertiary zone). Luria (1970) also postulated that reconstitution of lost functions can be achieved by two major types of functional reorganization i.e. intra-systemic reorganization and inter-systemic reorganization. Intra-systemic performance moves the performance of behaviour down or up within the central nervous system as a way of teaching the patient improved performance of that behaviour. For e.g. teaching the patient to first articulate any sound and then to produce a word. Although the directional interpretation is open to debate, but Luria seems to consider that an upward movement of reorganization is more feasible. Inter-systemic reorganization introduces into the performance of an act a functional system or set of behaviour that was not previously integral to that performance. With this type of reorganization the major factor on which reorganization is based comes from an entirely different functional system.

It is thus apparent in the present study that improvement seen in patients was achieved through intra-systemic reorganization. Functional reorganization was achieved in a hierarchical order from “lower to higher” level. First, reorganization of the functions of the primary zone was achieved i.e. attention and visual processing, followed by the functions of the secondary zone i.e. information processing and lastly the functions of the tertiary zone i.e. executive functioning was retrained. As the processing of information is influenced by memory and emotions, therefore in memory training was mediated in between.

It is thus clear that improvement seen in the neuropsychological deficits of patients with TBI is the result of the reorganization of functional zones. Maintaining alertness and concentration is the basic requirement for the performance of any task; therefore the impact of primary functional reorganization i.e. attention is seen indirectly during the vigilance maintained by the patients during the testing sessions and in the improvement shown in the visual scale; this was achieved through attention and visual processing exercises. Fine motor coordination, reading and arithmetic are activities which require integration and analysis of sensory information and therefore are the outcome of secondary functional reorganization and this was achieved through information processing and fine motor coordina-

tion exercise. Improvement in memory is found due to the memory techniques used during intervention. Finally, improvement in the intelligence scale, writing skills and spelling is the result of tertiary functional reorganization achieved through executive functioning techniques. As there was no neuroimaging studies conducted before and after the intervention, commenting upon the physiological mechanism behind the recovery is not feasible. However, it is evident that remediation techniques consisting of drills and exercises bring significant change in the neuropsychological deficit of patients with TBI. Thus, there is no doubt that the brain has the ability to reorganize and repair itself, and NR provides stimulation to allow the brain to recover its lost functions.

It is also evident that improvement seen in patients with TBI was the outcome of NR as all the patients were free from any form of medication and were only receiving NR. Secondly, the improvements found in patients cannot be attributed to spontaneous recovery as all the patients were selected after 1 year of injury and spontaneous recovery is observed only in the initial examination few months after injury. Cicerone et al. (2005) and Yu, (1976) have also shown that spontaneous recovery occurs during the first few weeks and months, after injury. Leon-Carrion & Machuca-Murga (2001) analyzed the course of post-TBI cognitive deficits in patients who did not receive NR; the study involved 28 subjects with severe TBI who were neuropsychologically assessed at 8 months post-TBI and again, 19 months later. Results showed no significant differences between the two neuropsychological exams and no spontaneous recovery beyond the 8 month post-TBI. Neurocognitive deficits consequential to TBI appeared to be established within the first 8 months post-trauma.

The study also supports the use of paper pencil techniques which provide stimulation to remediate neuropsychological deficits. There is enough evidence in support of computer based techniques which are found effective in remediating neuropsychological deficit (Chen et al., 1997; Cicerone et al., 2011; Chantsoulis et al., 2015), however, there is a lack of studies which promote the use of paper-pencil techniques. Thus, the study provides evidence for non-computer based techniques useful for NR which can be utilized for patients who are computer illiterate.

The study thus supports the effectiveness of NR in remediating neuropsychological deficits seen in patients with TBI. This is consistent with the findings of Ho and & Bennett (1997) and Cicerone et al. (2000, 2011) in their review. The review supports the view that there is substantial evidence to support interventions for attention, memory, social communication skills, executive function, and for comprehensive-holistic NR after TBI. In contrast to the findings of the current study, Rohling et al. (2009) and ECRI Institute (ECRI, 2010) found no significant impact of CR on deficits associated with attention, memory, visuospatial, and executive function, or to treat multiple areas of cognitive functioning.

It can thus be concluded from the present study that patients with TBI have major neuropsychological deficits which may persist years after injury. When these deficits are intervened through neuropsychological rehabilitation there is significant improvement in the neuropsychological deficits. Also the paper pencil

techniques used in Brainwave –R and Talking Pen are found to be useful in remediating the neuropsychological deficits of patients with TBI. However, the sample size of the study was quite small therefore more elaborate research in this direction is required and there is a scope to study the maintenance effect of NR. The mechanism behind recovery is also questionable as there were no physiological investigation or neuroimaging studies incorporated with NR. The effect of co-existing factors like anxiety and depression were also not controlled in the study.

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