Efficacy of Cognitive Remediation and Neurofeedback Training in Patients with Schizophrenia: A Randomized Control Trail

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Abstract

Introduction: Cognitive impairment is a core symptom in schizophrenia that has a significant impact on psychosocial function, but shows a weak response to pharmacological treatment. Consequently, a variety of non pharmacological interventions have tried to find out suitable out come in patients with schizophrenia. The present study was to first to find out can cognitive remediation and neurofeedback training with pharmacological intervention can bring batter functional outcome in patients with schizophrenia. **Method:** Twenty Schizophrenia diagnosed patients were selected. The participants were examined before intervention started and after completion of cognitive remediation and neurofeedback training the post assessment were performed. The assessments were done using the Socio Demographic and Clinical Data Sheet, Positive and Negative Syndrome Scale, Cognitive Symptom Checklist, Digit Symbol Substitution Test, PGI Memory Scale, Trail Making Test, Wisconsin Card Sorting Test. The data were analyzed via SPSS-21.Mean, standard deviation and repeated measures analysis were used to analyze the data. **Results:** After receiving the combination treatment of cognitive remediation, neurofeedback training and pharmacological interventions brigs better out come in compare to only pharmacological intervention. The post intervention findings revealed that significant improvement in psychopathology (Z-3.80) significant at the level of P .001, and the same findings reflecting in improvement in attention (Z-3.790) significant at the level of P .001. Memory and executive functions brings the same results. **Conclusion:** Cognitive remediation, neurofeedback training and pharmacological interventions brings better out come in compare to pharmacological intervention alone.

Keywords: Schizophrenia, Cognitive remediation, Neurofeedback training and Pharmcological intervention

Introduction

Schizophrenia is a severe and chronic mental disorder characterized not only by positive symptoms such as hallucinations and delusions, but also by pervasive **cognitive impairments** that affect attention, memory, executive functioning, and processing speed. These cognitive deficits are considered a core feature of the illness

and are strongly associated with poor functional outcomes, including difficulties in employment, social interaction, and independent living (Green, 2016; Nuechterlein et al., 2019). Importantly, these cognitive limitations often persist even when psychotic symptoms are adequately managed through antipsychotic medication, highlighting the need for specialized interventions targeting cognition (Barch & Ceaser, 2012). Cognitive Remediation Training (CRT) has emerged as a leading non-pharmacological intervention designed to improve cognitive functioning in individuals with schizophrenia. CRT involves structured, repetitive cognitive exercises—computerized or therapist-led—intended to enhance neurocognitive processes through learning-based strategies and neuroplasticity. Meta-analytic evidence demonstrates that CRT produces **small-to-moderate improvements** in global cognition and modest but meaningful gains in functional outcomes, particularly when combined with psychosocial rehabilitation or strategy coaching (Wykes et al., 2011; Lejeune et al., 2021). These findings support CRT as a recommended component of comprehensive recovery-oriented care.

In parallel, **Neurofeedback Training (NF)**, a form of biofeedback that provides real-time information about neural activity (typically through EEG), is gaining attention as an innovative tool for modulating dysfunctional brain patterns in schizophrenia. NF aims to teach individuals to self-regulate specific brainwave frequencies to improve attention, emotional regulation, and cognitive performance. Emerging evidence suggests that NF can lead to improvements in symptom severity, cognitive processes, and neural markers such as EEG coherence and brain-derived neurotrophic factor (BDNF) (Markiewicz et al., 2021; Li et al., 2024). Although research is still in early stages compared with CRT, systematic reviews indicate that NF is **feasible, safe, and potentially beneficial**, warranting further controlled trials (Oprea et al., 2024).

Given that CRT focuses on enhancing cognitive processes through structured practice and NF aims to optimize underlying neural states, combining these two approaches may offer synergistic benefits. Theoretical models suggest that neurofeedback-induced modulation of attention and arousal systems could increase the brain's receptivity to cognitive training, potentially amplifying learning effects. However, empirical evidence on integrated CRT+NF interventions remains limited, underscoring the need for rigorous research to evaluate combined efficacy.
Thus, examining Cognitive Remediation Training and Neurofeedback Training is timely and essential for developing more effective, neuroscience-informed interventions aimed at improving cognitive and functional outcomes in schizophrenia.

Materials and methods

The study was conducted at Institute of Mental Health and Hospital, Agra. Total 25 patients diagnosed with schizophrenia have been recruited form inpatients department of the institute. Out of 25 patients, 20 patients fulfilled the inclusion and exclusion criteria. These 20 patients were randomly assigned to CRT + NFT + TAU group and TAU group. All 20 patients were assessed at base level by following socio demographic and clinical data sheet, positive and negative syndrome scale, cognitive symptom checklist, digit symbol substitution test, PGI memory scale, trail making test, Wisconsin card sorting test. The same test evaluated at post assessment. The post assessment shave carried after completion of 30 days training of cognitive remediation.

Inclusion Criteria

- Patients with schizophrenia diagnosed according to ICD-10 criteria.
- Age range between 20-45 years.
- Patients having minimum education up to 5th std
- Duration of illness 2 to 5 years
- Patients who are on pharmacological treatment as usual
- Cooperative and able to understand Hindi or English

Exclusion Criteria

- Patients with a history of co-morbid psychiatric problems.
- Patients with a history of intellectual disability.
- Patients with a history of neurological problems such as epilepsy, head injury etc.
- Patients with a history of substance dependence.
- Patients who has received ECT within last 6 months.
- Those having history of major medical and physical problem.

Tools to be Used

- Socio Demographic and Clinical Data Sheet
- Positive and Negative Syndrome Scale by Kay et al. (1987)
- Cognitive Symptom Checklist by O'Hara et al. (2002)
- Digit Symbol Substitution Test, Wechsler (1981)
- PGI Memory Scale, Pershad and Wig (1976)
- Trail Making Test, Reitan (1958)
- Wisconsin Card Sorting Test, Heaton (1981)

Research design: Pre to post comparative research design.

Training module

Training package mainly consists cognitive remediation training for 30 sessions in five week, 6 day per week. Cognitive remediation training module adapted from brainwave- R. Brainwave-R is a comprehendsive pen-and-paper based cognitive rehabilitation program that is divided into five hierarchically graded modules: Attention, Visual Processing, Memory, Information Processing, and Executive Functions. Although in present study three modules will be taken for cognitive remediation training.

Attention Remediation Training

That module will help the patients to remediate their sustain, selective, alternating and divided attention through practice. Speed of information processing is an important aspect of attention, in module addressing each level of attention in increasing patient's speed and processing demands. It involves the techniques like paced random number, word targeting, category targeting, reverse counting, task maintenance, number blocks, decoding, simultaneous tasks, self-evaluation awareness etc.

Memory Remediation Training

This module has been designed to teach the patients about memory processes and emphasizes the use of strategies to compensate for memory problems. The memory process involves encoding, organization, maintaining the information in working memory (short term memory), consolidating or storing information into long term memory and retrieval of storage information when needed. In brainwave R module have several technique like learning the stage of memory, types of memory, retrieval, external and internal aids, learning new skills, card matching, functional memory exercises and some other techniques.

Executive Function Remediation Training

This module divided into two sections. Part one teaches the patients about executive function and strategies that can be used to compensate for deficits in this area. Part two provides a choice of projects for the patients to organize, plan, and execute using technique that though in part one. It's includes tasks like self-organization, planning, cognitive flexibility, goal setting, self-planning, initiation and regulation some other similar tasks.

Neuro-feedback Training

Alpha brain wave training will be given by computerized version of NeXus-4. Electrode will be placed on C3 and C4 region of the brain. 30 minutes regular neuro-feedback training for 30 days, six days in week for five week have given to subjects.

Results

Table-1: Comparison between CRT+ NFT+ TAU and TAU group at baseline on socio-demographic and clinical variables

Variable		CRT+NFT+TAU Mean ± SD, Number (%)	TAU Mean ± SD, Number (%)	F/ χ^2
Education	8th Pass	4 (40%)	4 (40%)	5.831
	10th& 12th Pass	3 (30%)	3 (30%)	
	Graduation	2 (20%)	2 (20%)	
	Above Graduation	1 (10%)	1 (10%)	
Marital Status	Married	5 (50%)	5 (50%)	0.301
	Unmarried	5 (50%)	5 (50%)	
Religion	Hindu	9 (90%)	10 (100%)	2.105
	Muslim	1 (10%)	0 (0%)	
Residence	Urban	4 (40%)	3 (30%)	1.238
	Semi Urban	1 (10%)	2 (20%)	
	Rural	5 (50%)	5 (50%)	
Employment Status	Employed	6 (60%)	6 (60%)	0.307
	Unemployed	4 (40%)	4 (40%)	
Income	0-4999	3 (30%)	2 (20%)	1.895
	5000-9999	5 (50%)	5 (50%)	
	10000-14999	2 (20%)	3 (30%)	
Family	Joint Family	7 (70%)	5 (50%	2.165
	Nuclear Family	3 (30%)	5 (50%)	
Age		29.10±1.52	29.00±2.21	0.710
Age of Onset		25.00±1.05	24.80±2.10	0.587
Total Duration of Illness		4.10±.73	4.20±.92	0.125

**Significant at p<0.05

Table- 2: Comparison between CRT+NFT+TAU group and TAU group on PANSS and Digit Symbol Test scores at base level

Variable	Group (Mean ± SD)		Mean Rank		Z
	CRT+NFT+ TAU	TAU	CRT+NFT +TAU	TAU	
PANSS Positive	23.30±2.21	23.60±1.51	9.75	11.25	**0.578**
PANSS Negative	26.60±1.84	26.15±1.67	10.55	10.44	**0.039**
PANSS General	55.70±2.11	54.30±3.92	11.75	8.25	**1.745**
PANSS Total	105.60±4.27	104.40±5.10	12.24	11.75	**1.634**
Digit Symbol Test	17.90±2.64	16.20±1.99	12.75	8.25	**0.582**

*Significant at p<0.05,**Significant at p<0.01

Table-3: Comparison between CRT+NFT+TAU group and TAU group on PGI Memory Scale scores at base level

Variable	Group (Mean ± SD)		Mean Rank		Z
	CRT+NFT+ TAU	TAU	CRT+NFT +TAU	TAU	
PGI Memory Total	21.70±1.51	21.35±1.34	9.95	11.05	**0.425**
Remote Memory	00.00±00	00.00±00	10.50	10.50	**0.000**
Recent Memory	00.00±00	00.00±00	10.50	10.50	**0.000**
Mental Balance	2.90±0.32	2.90±0.32	10.50	10.50	**0.000**
Attention and Concentration	2.80±0.42	2.76±0.48	11.00	10.00	**0.503**
Delayed Recall	2.60±0.97	2.50±0.97	10.95	10.05	**0.449**
Immediate Recall	2.90±0.32	2.80±0.42	11.00	10.00	**0.610**
Verbal Retention for Similar Pairs	2.10±1.20	2.50±0.97	9.45	11.55	**0.906**
Verbal Retention for Dissimilar Pairs	2.70±0.48	2.80±0.42	10.00	11.00	**0.503**
Visual Retention	2.40±1.26	2.70±0.48	10.70	10.30	**0.199**
Recognition	3.00±0.00	2.80±0.42	11.50	9.50	**1.453**

*Significant at p<0.05,**Significant at p<0.01

Table-4: Comparison between CRT+NFT+TAU group and TAU group on Trail Making Test and Cognitive Symptoms Check List scores at base level

Variable	Group (Mean ± SD)		Mean Rank		Z
	CRT+NFT+ TAU	TAU	CRT+NFT +TAU	TAU	
Trail Making Part- A	169.80±16.89	165.40±18.16	11.35	9.65	**0.644**
Trail Making Part- B	286.80±34.15	266.50±49.39	9.65	9.00	**1.330**
CSCL Total	166.80±7.60	169.90±5.90	11.45	9.55	**1.101**
Attention / Concentration	34.40±3.37	33.60±4.70	10.80	10.20	**0.723**
Executive Function	57.10±3.84	57.20±3.32	9.00	12.00	**0.229**
Memory	46.90±5.70	50.00±7.15	10.80	10.20	**1.142**
Visual Processing	14.20±1.87	13.80±2.85	9.20	11.80	**0.229**
Language	14.20±3.05	15.30±2.95	9.05	11.95	**0.997**

***Significant at p<0.05,**Significant at p<0.01**

Table-5: Comparison between CRT+NFT+TAU group and TAU group on Wisconsin Card Sorting Test scores at base level

Variable	Group (Mean ± SD)		Mean Rank		Z
	CRT+NFT+ TAU	TAU	CRT+NFT+ TAU	TAU	
Number of trials Administered	128.00±00	128.00±00	10.50	10.50	**0.000**
Total Number of Correct	61.20±10.20	63.10±12.87	9.90	11.10	**0.454**
Total Number of Errors	66.80±10.20	64.90±12.87	11.10	9.90	**0.454**
Percent Errors	52.20±7.80	50.72±10.00	11.20	9.80	**0.532**
Perseverative Responses	37.40±14.82	39.40±15.48	10.15	10.85	**0.265**
Percent Perseverative Responses	29.20±11.61	30.90±12.02	10.05	10.95	**0.341**
Perseverative Errors	32.90±11.16	36.30±14.41	9.70	11.30	**0.607**
Percent Perseverative Errors	25.90±8.74	28.50±11.29	9.80	11.20	**0.532**
Non-perseverative Errors	33.90±13.31	28.90±11.35	11.95	9.05	**1.102**

Percent Non-perseverative Errors	29.40±14.52	25.00±9.91	11.45	9.55	**0.722**
Conceptual Level Responses	35.60±13.56	37.30±17.19	10.25	10.75	**0.189**
Percent Conceptual Level Responses	27.10±9.83	29.09±13.45	9.95	11.05	**0.417**
Number of Categories Completed	6.00±0.00	1.50±.97	10.80	10.20	**0.240**
Trials to Complete First Category	12.60±2.11	64.30±42.45	9.75	11.25	**0.571**

***Significant at p<0.05,**Significant at p<0.01**

Results at base level indication CRT+NFT= TAU group and TAU group did not differ to each other at base level

Table-6: Comparison between CRT+NFT+TAU group and TAU group on PANSS and Digit Symbol Test scores at post intervention phase

Variable	Group (Mean ± SD)		Mean Rank		Z
	CRT+NFT+TAU	TAU	CRT+NFT+TAU	TAU	
PANSS Positive	7.90±0.99	14.60±1.17	5.50	15.50	**3.845****
PANSS Negative	8.40±1.57	19.20±1.39	5.50	15.50	**3.833****
PANSS General	17.60±1.64	38.00±1.63	5.50	15.50	**3.810****
PANSS Total	33.90±3.57	71.90±3.39	5.50	15.50	**3.801****
Digit Symbol Test	63.90±2.80	30.80±2.78	15.50	5.50	**3.790****

***Significant at p<0.05,**Significant at p<0.01**

Table-7: Comparison between CRT+NFT+TAU group and TAU group on PGI Memory Scale scores at post intervention phase

Variable	Group (Mean ± SD)		Mean Rank		Z
	CRT+NFT+ TAU	TAU	CRT+NFT+ TAU	TAU	
PGI Memory Total	00.00±00.00	18.50±2.27	5.50	15.50	4.044**
Remote Memory	00.00±00	00.00±00	10.50	10.50	0.000
Recent Memory	00.00±00	00.00±00	10.50	10.50	0.000
Mental Balance	00.00±00	2.70±0.48	5.50	15.50	4.147**
Attention and Concentration	00.00±00	2.40±0.52	5.50	15.50	4.119**
Delayed Recall	00.00±00	2.40±0.52	5.50	15.50	4.119**
Immediate Recall	00.00±00	2.30±0.48	5.50	15.50	4.147**
Verbal Retention for Similar Pairs	00.00±00	0.40±0.84	9.50	11.50	1.453
Verbal Retention for Dissimilar Pairs	00.00±00	2.40±0.52	5.50	15.50	4.119**
Visual Retention	00.00±00	2.60±0.52	5.50	15.50	4.119**
Recognition	00.00±00	2.90±0.32	6.05	14.95	4.264**

*Significant at p<0.05,**Significant at p<0.01

Table-8: Comparison between CRT+NFT+TAU group and TAU group on Trail Making Test and Cognitive Symptoms Check List scores at post intervention phase

Variable	Group (Mean ± SD)		Mean Rank		Z
	CRT+NFT+TAU	TAU	CRT+NFT+ TAU	TAU	
Trail Making Part- A	26.10±2.42	69.90±10.47	5.50	15.50	3.785**
Trail Making Part- B	40.10±2.84	163.10±35.07	5.50	15.50	3.784**
CSCL Total	12.70±2.49	91.50±5.08	5.50	15.50	3.791**
Attention / Concentration	04.10±0.87	23.80±2.34	5.50	15.50	3.836**
Executive Function	06.00±1.41	28.10±2.28	5.50	15.50	3.817**
Memory	02.60±0.84	21.80±2.29	5.50	15.50	3.827**
Visual Processing	00.00±00.00	9.80±1.62	5.50	15.50	4.054**
Language	00.00±00.00	8.00±0.94	5.50	15.50	4.075**

*Significant at p<0.05,**Significant at p<0.01

Table-9: Comparison between CRT+NFT+TAU group and TAU group on Wisconsin Card Sorting Test scores at post intervention phase

Variable	Group (Mean ± SD)		Mean Rank		Z
	CRT+NFT+ TAU	TAU	CRT+NFT+ TAU	TAU	
Number of trials Administered	83.90±12.52	128.00±0.00	5.50	15.50	4.040**
Total Number of Correct	67.60±8.72	76.00±13.17	8.20	12.80	1.744
Total Number of Errors	17.00±8.01	52.00±13.17	5.50	15.50	3.784**
Percent Errors	19.91±6.94	40.89±10.38	5.70	15.30	3.630**
Perseverative Responses	12.30±5.01	35.70±14.17	5.70	15.30	3.638**
Percent Perseverative Responses	14.24±4.40	28.00±11.15	6.50	14.50	3.027**
Perseverative Errors	10.40±3.83	31.10±12.87	5.85	15.15	3.523**
Percent Perseverative Errors	12.15±3.45	24.49±9.91	6.55	14.45	2.989**
Non-perseverative Errors	05.60±3.50	19.90±7.05	5.50	15.50	3.785**
Percent Non-perseverative Errors	06.22±3.59	15.79±5.38	5.90	15.10	3.485**
Conceptual Level Responses	64.30±6.27	58.80±15.02	11.50	9.50	0.762
Percent Conceptual Level Responses	77.50±8.82	46.00±11.81	15.40	5.60	3.708**
Number of Categories Completed	6.00±0.00	3.50±0.85	15.50	5.50	4.141**
Trials to Complete First Category	12.60±2.11	23.10±13.64	7.65	13.35	2.167*

***Significant at p<0.05,**Significant at p<0.01**

At post level assessment indication both the group differ significantly in all outcome variables like improvement in psychopathology and neuro-cognitive functions.

Discussion

The present study examined the effectiveness of a combined intervention comprising Cognitive Remediation Training (CRT) and Neurofeedback Training (NFT) in addition to Treatment-As-Usual (TAU) among patients with schizophrenia. The results indicate that the CRT+NFT+TAU group demonstrated significantly better outcomes in both symptom reduction and cognitive performance compared to the TAU-only group.

Participants who received the combined intervention showed substantially lower scores on PANSS Positive, Negative, General Psychopathology, and Total scales. The consistently lower mean ranks and statistically significant Z-values ($p < .01$) suggest a robust therapeutic impact of the multimodal intervention. These results are consistent with previous findings showing that CRT enhances cognitive processes such as attention, memory, and executive functioning, which can indirectly contribute to reductions in symptom severity (Wykes & Huddy, 2009; Twamley et al., 2003). Moreover, CRT has been associated with improved functional outcomes, likely due to strengthened neural efficiency and cognitive flexibility (Wykes et al., 2011).

Similarly, neurofeedback training has shown promise in modulating abnormal brain activity patterns commonly observed in schizophrenia. Research suggests that NFT can improve self-regulation of neural oscillations, thereby contributing to symptom stabilization and emotional regulation (Nan et al., 2012; Markiewicz & Dobrowolska, 2022). The improvement in general psychopathology in the present study supports the growing evidence that EEG-based neurofeedback may serve as an effective adjunctive treatment.

The **Digit Symbol Test** results further highlight the cognitive benefits of the combined intervention. Participants in the CRT+NFT+TAU group scored significantly higher, indicating improved processing speed and working memory—domains particularly impaired in schizophrenia (Dickinson et al., 2007). This aligns with prior studies showing that CRT enhances processing speed (McGurk et al., 2007), while NFT contributes to improved attentional control (Gruzelier, 2014).

The PGI Memory Scale results reveal a striking difference between the CRT+NFT+TAU group and the TAU-only group. Across nearly all memory domains—including Mental Balance, Attention & Concentration, Delayed Recall, Immediate Recall, Verbal Retention of Dissimilar Pairs, Visual Retention, and Recognition—the TAU group showed measurable impairments, whereas the CRT+NFT+TAU group consistently scored 0 (indicating no memory deficits). These highly significant Z-

values ($p < .01$) suggest that the combined intervention produced meaningful improvements in cognitive functioning related to memory processes.

The most prominent improvements were observed in **Attention and Concentration**, **Delayed Recall**, **Immediate Recall**, **Mental Balance**, **Visual Retention**, and **Recognition**. These findings align with existing evidence showing that CRT enhances core cognitive domains such as attention, processing speed, working memory, and learning in patients with schizophrenia (Wykes & Huddy, 2009; McGurk et al., 2007). Since attention and working memory act as foundational skills for recall, the improvements observed in recall-based subtests may be attributed to strengthened cognitive control mechanisms developed through CRT.

Similarly, **Neurofeedback Training (NFT)** has been shown to modulate dysfunctional neural oscillations involved in attention, memory consolidation, and executive functioning. Studies demonstrate that neurofeedback improves attentional regulation, stabilizes neural networks, and enhances memory-related performance (Gruzelier, 2014; Nan et al., 2012). Therefore, the combined delivery of CRT and NFT likely produced additive or synergistic effects, resulting in sharper cognitive performance in the CRT+NFT+TAU group.

Interestingly, **Remote Memory** and **Recent Memory** did not differ between the groups ($Z = 0.00$), suggesting that these memory domains remained unaffected by either intervention. Remote and autobiographical memories are relatively stable and are not typically impaired in schizophrenia, making them less sensitive to cognitive remediation or neurofeedback interventions. Thus, these findings are consistent with prior literature indicating that cognitive interventions primarily influence working memory, attention, and learning-based memory, rather than long-term stored memories (Barch & Ceaser, 2012).

The significant improvement in **Recognition** further supports the effectiveness of the CRT+NFT+TAU intervention, as recognition memory relies on intact attention, encoding efficiency, and retrieval strategies—areas directly targeted by CRT protocols.

Overall, the present table shows that the combined intervention of CRT and NFT produced meaningful improvements across critical memory domains in schizophrenia, surpassing the effects of TAU alone. These results support the growing body of evidence that multimodal cognitive interventions can significantly enhance neuropsychological functioning and may serve as effective adjunctive treatments in psychiatric rehabilitation. Overall, the findings support the growing

consensus that **multimodal cognitive interventions** yield superior outcomes compared to pharmacotherapy alone. The combination of CRT and NFT appears to produce synergistic effects, targeting both the neurocognitive and neurophysiological underpinnings of schizophrenia. Future research should consider long-term follow-up and neuroimaging methods to better understand the durability and neural mechanisms of these improvements.

The results from the Trail Making Test (TMT) and the Cognitive Screening Checklist (CSCL) indicate that the combined intervention of CRT + NFT + TAU led to significant improvements in processing speed, attention, executive functioning, memory, visual processing, and language abilities among patients with schizophrenia. In contrast, the TAU group showed substantial impairments across all these cognitive domains, as reflected in their higher mean scores and mean ranks. The consistently significant Z-values ($p < .01$) across all variables further highlight the superiority of the combined intervention over routine care alone. Participants in the CRT+NFT+TAU group demonstrated much faster completion times on TMT-A and TMT-B, indicating enhanced processing speed, cognitive flexibility, and executive control. These improvements align with prior findings demonstrating that CRT effectively targets and enhances cognitive domains involving attention shifting, sequencing, and visuomotor speed (Wykes et al., 2011; McGurk et al., 2007). TMT-B performance is frequently associated with higher-order executive functions, which tend to be impaired in schizophrenia (Bowie & Harvey, 2006). The significant improvement in these scores suggests that CRT, combined with NFT, facilitated better neural efficiency and cognitive control.

NFT may contribute to these outcomes by regulating dysfunctional brain activity associated with attentional and executive deficits. Studies indicate that neurofeedback enhances attentional stability and improves functional connectivity of networks involved in executive control (Gruzelier, 2014; Enriquez-Geppert et al., 2017). Thus, the accelerated TMT performance may reflect synergistic gains from both interventions.

The CRT+NFT+TAU group showed substantially lower CSCL Total scores and superior performance across all subdomains, including Attention/Concentration, Executive Function, Memory, Visual Processing, and Language. These domains are typically impaired in schizophrenia due to widespread disruptions in cognitive networks (Mesholam-Gately et al., 2009). The large difference between groups highlights the broad cognitive benefits of the combined intervention. Attention and Concentration improvements are consistent with earlier research showing that CRT

strengthens sustained attention, vigilance, and cognitive control. Since NFT directly enhances attentional regulation through neurophysiological conditioning, gains in this domain may be particularly robust (Nan et al., 2012). Executive Function scores also improved in the intervention group, which parallels research showing that CRT enhances planning, problem-solving, and cognitive flexibility, while NFT helps optimize frontal network functioning. Memory improvements may reflect heightened encoding efficiency and working memory capacity—key areas shown to improve with CRT (Wykes & Huddy, 2009). Visual Processing and Language improvements were also notable, with the CRT+NFT+TAU group showing no deficits (mean = 0.00), compared to clear impairments in the TAU group. Cognitive remediation programs typically include visual-spatial exercises and language-based tasks, which could account for these gains. Enhanced attentional control from NFT may further support improved visual and language processing.

The Wisconsin Card Sorting Test (WCST) results indicate substantial cognitive advantages for patients who received CRT + NFT + TAU compared with those who received only TAU. The WCST evaluates executive functioning, including cognitive flexibility, problem-solving, working memory, set-shifting, and the ability to use feedback—domains that are typically impaired in schizophrenia. The pattern of results strongly favors the combined intervention.

The Number of Trials Administered was significantly lower in the CRT+NFT+TAU group, suggesting greater efficiency in understanding task demands and achieving the test's objectives. In contrast, the TAU group required the maximum number of trials, reflecting persistent difficulty in rule learning and set shifting. This matches existing literature showing that schizophrenia patients often need more trials due to reduced cognitive flexibility (Barch & Ceaser, 2012).

Although **Total Number of Correct responses** did not differ significantly between groups, the CRT+NFT+TAU group made far fewer **Total Errors**, with highly significant Z-values. This suggests that while both groups were capable of generating correct responses, the intervention group relied on more consistent and accurate cognitive strategies. The reduction in **Percent Errors** further reinforces improved task efficiency and attentional control. These improvements correspond with known effects of CRT, which targets cognitive flexibility, error monitoring, and strategy use, leading to reductions in perseveration and random responding (Wykes & Huddy, 2009; McGurk et al., 2007). One of the most meaningful findings is the significant reduction in **Perseverative Responses** and **Perseverative Errors** in the CRT+NFT+TAU group. Perseveration is a hallmark deficit in schizophrenia and

reflects impaired ability to shift cognitive sets or abandon ineffective strategies. Substantially lower perseveration rates indicate enhanced cognitive flexibility and improved ability to integrate feedback—abilities known to improve with both CRT and neurofeedback. NFT likely played an important role by strengthening frontal lobe networks responsible for inhibitory control, error monitoring, and sustained attention (Enriquez-Geppert et al., 2017; Gruzelier, 2014).

Significant reductions in **Non-Perseverative Errors** in the intervention group suggest improvements not only in flexibility but also in attentional consistency and conceptual understanding. Improvements in these domains reflect strengthened working memory capacity and improved processing efficiency. Although **Conceptual Level Responses** (raw score) did not differ significantly, the **Percent of Conceptual Level Responses** was significantly higher in the CRT+NFT+TAU group. This indicates better abstraction ability, rule acquisition, and high-level reasoning—central deficits in schizophrenia. This improvement is coherent with CRT literature linking structured cognitive exercises to gains in higher-order problem-solving (Wykes et al., 2011).

The intervention group completed the maximum **6 Categories**, whereas the TAU group averaged only 3.5 categories. Completing more categories is widely recognized as one of the strongest indicators of intact executive functioning on the WCST. This finding suggests the intervention substantially improved rule learning and set-shifting. Additionally, the significantly lower number of **Trials to Complete the First Category** in the CRT+NFT+TAU group reflects faster initial learning and better adaptation to feedback, both of which are frequently compromised in schizophrenia the similar findings reported by (Wykes et al., 2011; Twamley et al., 2003; Gruzelier, 2014; Enriquez-Geppert et al., 2017).

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