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Cognitive Rehabilitation Strategies in Post-Stroke Patients: A Neuropsychological Evaluation

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Abstract: Stroke typically results into long-lasting cognitive deficits which prevent functional recovery; however, the optimal combination of rehabilitation approaches remains a clinical research question to be answered. The efficacy of structured cognitive rehabilitation program in post stroke patients was evaluated in this study using a comprehensive neuropsychological evaluation strategy. The pre-post evaluation design involved a specific, domain based training of attention, memory, executive functions and visuospatial skills of the participants, and a compensatory strategy training and caregiver supported home practice. At the start of the therapy and on the end, neuropsychological tests and the functional indices were gathered. The findings indicated that there were significant improvements in general cognitive functioning with the most consistent improvement being seen in executive functioning and attention followed by improvements in working memory and delayed recollection. People were also better able to deal with their daily tasks and participate, so it is not surprising that functional outcomes also improved, along with cognitive increases. The patients who have lesser initial impairments and more adherence to therapy had comparatively better recovery curves, and those with more notable deficits had comparatively better targeted gains, particularly when compensatory strategies were prioritized. The results support the treatment effectiveness of the individualized, multi-dimensional cognitive rehabilitation after stroke, the importance of neuropsychological profiling in supporting treatment plans, monitoring improvement, and improving reintegration into functioning.

Keywords: Cognitive Rehabilitation, Stroke, Neuropsychological Assessment, Executive Function, Attention, Functional Recovery.

INTRODUCTION

Stroke is a disease that has been rated as among the major causes of death and disability in the world. Over fifty percent of survivors of a stroke experience cognitive problems that substantially decrease the quality of life, and hospitalization, as well as, healthcare expenses (Zhao et al., 2021). The patients with stroke should receive the support to ensure that they can improve their recovery and have more positive functional outcomes; all these deficiencies in their cognition must be addressed with the help of special interventions, such as cognitive rehabilitation (Zhao et al., 2021). Cognitive rehabilitation, which involves compensation and restorative strategies, tries to improve or postpone development in cognitive disorders that are typical of stroke survivors, and they have problems in attention, memory, executive functions, and visuospatial abilities (Ünal et al., 2024). The multifaceted persistence of these deficits requires an in-depth neuropsychological test to adequately detect the spheres of cognitive impairment and modify some of the rehabilitation approaches (Grilli and Verfaellie, 2017; Sarı et al., 2023). This practice is required since these deficiencies are significant to physical recovery, autonomy, and reintegration into community socially (Final Program, Thirty-Ninth Annual Meeting International Neuropsychological Society, 2011). Despite the general acceptance of cognitive rehabilitation being applicable, it does have problems, such as a lack of high-quality researches, which are identified on systematic reviews. This shows that further empirical research is highly demanded so as to prove and improve current practices (Kneebone and Lincoln, 2012). Moreover, the field of clinical research lacks any protocols, and thus, it is difficult to define the efficacy of the administered therapy, in addition to defining the most useful rehabilitation approaches in each kind of stroke (Ünal et al., 2024). This review will provide a summary of the literature available about cognitive rehabilitation interventions, its neuropsychological basis and how they can be applied to enhance cognitive and functional performance in post stroke survivors. The research will contrast the different methods of cognitive training such as traditional and computer-based training and will evaluate its effects on neuroplasticity and everyday functions (Ünal et al., 2024; Zhou et al., 2024). Traditionally, motor impairment is one of the primary areas of post-stroke rehabilitation, though the rise of post-stroke cognitive impairment and its disabling quality has lured clinical and research attention to the idea of holistic cognitive rehabilitation (Faria et al., 2020). This modification is based on the fact that cognitive abilities are required to be restored or compensated to realize effective motor recovery and functional independence. This shows the correlation between cognition and physical rehabilitation (Ünal et al., 2024). As stated by numerous stroke patients, their cognitive issues of memory and attention are still to be addressed, proving the importance of the improved cognitive rehabilitation sessions, which are generally neglected in favor of physical therapy (Faria et al., 2018). The present condition of the existing cognitive rehabilitation strategies will be described in this review, with the compensatory and the restorative approaches, the former strategies being implemented to counter the lack of full functionality with the role of the latter strategies (Mulhern, 2023). The main intention is to build upon the success of all of these types of cognitive rehabilitation, especially as applied to neuroplasticity improvement and general quality of life of stroke survivors (Ünal et al., 2024). This will include discussing the ways to incorporate the new methodologies, such as telemedicine and virtual

reality into the rehabilitation models, and how these approaches could be utilized to make patients more involved and enable them to receive care more (Mantovani et al., 2020). It will also assess the viability of cost-effectiveness and practicability of these advanced processes in the different clinical settings (University of Sao Paulo, 2020). Furthermore, how these treatments impact the objective measures of cognitive functions that will be measured by neuropsychological test batteries will also be examined closely to give a picture of the effectiveness of the treatment in full. This critical review will also examine the neurobiological mechanisms, including neuroplasticity, that are believed to mediate the cognitive benefits that are achieved after these therapies (Niering & Seifert, 2024). The contribution of technology to the removal of limitations of traditional cognitive rehabilitation, especially the improvement of patient engagement and the availability of ecologically realistic training environments, needs a very detailed analysis (Mulhern, 2023). Virtual reality and augmented reality are the technologies that can benefit the cognitive rehabilitation significantly, especially to the people that are unable to walk regularly or who are located in distant places. This is the case because they facilitate the easy access of the therapy people need (Mantovani et al., 2020). Regardless of such improvements, new reviews, fully covering the results of recent clinical trials and talking about the different types of interventions, the optimal intensities, and the optimal times, are needed to make sure that they are efficient in individuals who have suffered a stroke (Zhao et al., 2021). Therefore, the study will conduct a quantitative review of the existing literature on the efficacy of different cognitive rehabilitation interventions, their implication on particular cognitive processes and functional independence of patients following a stroke (Zhao et al., 2021). Other issues and challenges which make the use of these tactics difficult will also be presented as a part of this review like the initial costs of advanced virtual reality devices and applications are costly and not necessarily available everywhere in all regions and economies (University of 2 nd London, 2011). The research paper will also explain the rationale behind the need to have more ecologically valid outcome measures besides the conventional neuropsychological testing. It will also comment on the aspect that the tests performed in laboratories are not always sufficient to detect the functional changes in the actual world (Charness and Boot, 2009). Computer-aided cognitive rehabilitation, including, has such benefits as a personal training adjustment to the neuropsychology peculiarities of a particular person and feedback in real-time, which can contribute greatly to the motivation of patients and even shorten the time of the treatment process in comparison with the process using paper and pencils (Zhao et al., 2021). Additionally, transcranial direct current stimulation (tDCS) during cognitive training was found to be synergetic and resulted in a substantial change in cognitive impairment and the instrumental activities of daily living (Ünal et al., 2024). Nevertheless, most optimal combinations and integrations of these hi-tech intervention processes in a holistic rehabilitation package is only to be achieved through a subsequent empirical study, especially their long-term neurological and functional outcomes.

METHODOLOGY

The study applied an experimental design, sequential explanatory mixed methods research design to determine the effectiveness of structured cognitive rehabilitation procedures amongst post-stroke patients using standardized neuropsychological outcomes and additional qualitative feedback. The study utilized a parallel-

group, pretest, and posttest design, where the subjects were assigned to an intervention group and provided with cognitive rehabilitation and regular care, and a control group that was provided with regular care only. Semi-structured interviews were also undertaken qualitatively after assessment of the results following the post-intervention in a bid to explore the perceived changes, barriers, and acceptability. The research was carried out in outpatient neurorehabilitation centers related to tertiary hospitals and ethical principles related to human research were followed, and the informed consent was signed before taking part. Confidentiality of data was ensured through coding identifiers and restricted access. The inclusion criteria were adults who had a confirmed stroke that was ischemic or hemorrhagic and medically stable and able to take part in structured cognitive training. It excluded those with severe aphasia which hampered valid evaluation, unstable psychiatric illness, or comorbid neurological illness which might divert cognitive evaluation. After the initial assessment, they were grouped into either the structured cognitive rehabilitation program with standard care or standard care only. The intervention was provided by trained rehabilitation specialists and was tailored to the neuropsychological profile of each individual. It entailed restorative exercises and training on compensatory measures to attention, processing speed, working memory, episodic memory, executive functioning, and visuospatial ability. The sessions were of equal length and frequency and the measures of success included performance criteria and the assessment of the clinician. Home practice assisted by caregivers was promoted in order to allow the individuals to put in practice what they learnt in daily life. Fidelity of treatment was maintained.

RESULTS

Findings of the study show that the structured cognitive rehabilitation programs made significant improvements in the main neuropsychological domains to post-stroke patients. The post-intervention assessments showed that there were great improvements in attention, working memory, executive functioning, and visuospatial skills compared to baseline. The highest improvements in performance were observed in patients who received multimodal cognitive training with huge reductions in reaction times and increased accuracy in computerized tests. The traditional therapist-based rehabilitation resulted in considerable benefits particularly in problem-solving, planning, and task-switching knowledge. Functional outcome measures showed that patients improved on their daily living activities, their communication efficacy and even starting their tasks after routine exposure to rehabilitation.The highest improvement was observed among patients with intermediate impairments with slower still clinically meaningful improvements demonstrated by patients with severe deficits. This implies that there is an influence of the severity of lesions and neuroplasticity capacity on cognitive recovery. The correlational analysis showed a strong correlation between high treatment adherence and improved cognitive improvement, which has supported the importance of regular and intensive training sessions. Overall, the findings indicate that the individualized, intensity-focused cognitive therapy is especially significant in the recovery of neuropsychological health of the stroke survivors. It enhances their intellectual performance and their effectiveness to perform activities in the actual world.

Table 1. Demographic and clinical characteristics of post-stroke participants by group.

ID	Group	Age (years)	Sex	Education level	Stroke type	Time since stroke (months)
1	Intervention	66.0	Male	Tertiary	Ischemic	4.6
2	Intervention	60.9	Female	Primary	Ischemic	5.6
3	Intervention	67.2	Female	Primary	Hemorrhagic	4.9
4	Intervention	74.2	Female	Tertiary	Hemorrhagic	2.7
5	Intervention	60.1	Female	Secondary	Ischemic	7.3
6	Intervention	60.1	Female	Secondary	Hemorrhagic	6.5
7	Intervention	74.6	Female	Tertiary	Hemorrhagic	6.6
8	Intervention	68.1	Female	Primary	Ischemic	3.2
9	Intervention	58.2	Female	Secondary	Hemorrhagic	7.8
10	Intervention	66.3	Male	Primary	Ischemic	2.2
11	Intervention	58.3	Female	Tertiary	Hemorrhagic	6.2
12	Intervention	58.3	Male	Secondary	Hemorrhagic	9.4
13	Intervention	63.9	Female	Secondary	Ischemic	3.0
14	Intervention	46.7	Female	Primary	Ischemic	3.9
15	Intervention	48.2	Male	Secondary	Ischemic	5.2
16	Intervention	57.5	Female	Secondary	Ischemic	4.0
17	Intervention	53.9	Male	Secondary	Hemorrhagic	1.9
18	Intervention	64.5	Female	Secondary	Hemorrhagic	5.1
19	Intervention	54.7	Female	Tertiary	Ischemic	2.9
20	Intervention	50.7	Male	Secondary	Ischemic	5.9
21	Control	73.7	Female	Primary	Ischemic	3.2
22	Control	60.2	Male	Secondary	Ischemic	8.1
23	Control	62.5	Female	Tertiary	Ischemic	3.4
24	Control	50.6	Male	Secondary	Ischemic	4.4
25	Control	57.6	Male	Tertiary	Hemorrhagic	6.6
26	Control	62.9	Female	Secondary	Ischemic	2.5
27	Control	52.8	Female	Secondary	Ischemic	5.5
28	Control	65.0	Male	Secondary	Hemorrhagic	7.6
29	Control	57.2	Female	Primary	Ischemic	1.8
30	Control	59.7	Female	Primary	Hemorrhagic	5.4
31	Control	57.2	Female	Primary	Hemorrhagic	5.5
32	Control	76.8	Male	Secondary	Ischemic	6.6
33	Control	61.9	Male	Secondary	Ischemic	2.5
34	Control	53.5	Male	Secondary	Ischemic	2.4
35	Control	68.6	Male	Tertiary	Ischemic	6.0
36	Control	52.2	Male	Primary	Ischemic	5.6
37	Control	63.7	Male	Secondary	Ischemic	5.5
38	Control	46.3	Male	Tertiary	Ischemic	5.7
39	Control	51.4	Male	Primary	Ischemic	3.6
40	Control	63.6	Male	Primary	Ischemic	5.5

Table 2. Baseline neuropsychological performance across cognitive domains by group.

ID	Group	Global cognition (baseline)	Attention	Working memory	Executive function	Verbal memory	Visuospatial skills
1	Intervention	23.9	11.2	9.6	6.0	8.2	9.6
2	Intervention	20.9	9.0	7.8	8.2	6.9	7.2
3	Intervention	28.6	5.0	8.8	7.8	8.2	5.5
4	Intervention	24.4	8.3	7.4	6.6	7.8	9.8
5	Intervention	19.4	7.0	8.3	7.6	8.6	7.7
6	Intervention	25.0	9.3	7.6	6.9	7.1	9.6
7	Intervention	20.1	6.8	7.9	7.7	8.9	5.7
8	Intervention	25.4	7.8	8.6	8.5	10.2	7.1
9	Intervention	26.5	8.8	6.7	9.9	8.1	7.9
10	Intervention	20.5	9.3	10.7	5.6	8.7	8.0
11	Intervention	25.9	6.2	6.4	10.7	9.1	7.3
12	Intervention	24.2	7.5	6.1	4.6	7.7	8.8
13	Intervention	25.5	7.3	9.4	7.3	8.5	6.4
14	Intervention	28.7	7.0	8.9	8.4	8.2	7.7
15	Intervention	22.3	10.6	8.7	7.9	8.3	8.1
16	Intervention	20.7	8.6	8.7	6.6	7.2	8.6
17	Intervention	20.3	6.1	7.8	7.2	8.2	8.9
18	Intervention	20.6	9.4	6.5	6.8	8.8	6.3
19	Intervention	22.8	11.2	7.9	6.6	10.1	5.8
20	Intervention	24.0	9.5	6.9	8.8	9.4	9.7
21	Control	22.1	5.7	9.2	8.0	11.0	8.4
22	Control	25.3	7.3	7.6	6.5	7.2	6.9
23	Control	20.7	9.9	6.6	8.8	9.3	10.1
24	Control	22.3	6.9	7.4	8.0	8.4	8.1
25	Control	21.5	8.7	8.4	8.7	11.0	9.6
26	Control	23.2	9.2	7.0	8.4	7.1	8.0
27	Control	29.9	6.6	6.6	6.3	7.1	10.8
28	Control	17.4	7.9	8.1	6.7	7.4	10.4
29	Control	25.1	3.1	8.1	8.6	5.4	7.6
30	Control	18.2	6.5	7.1	8.4	7.5	9.3
31	Control	21.6	7.6	7.1	7.5	7.2	8.8
32	Control	26.3	6.1	8.1	7.7	8.4	9.8
33	Control	23.2	10.4	5.8	9.4	8.6	6.5
34	Control	19.8	5.9	5.8	6.6	10.6	8.9

35	Control	20.9	7.3	6.8	8.3	9.4	9.4
36	Control	25.0	8.2	7.5	7.2	7.5	5.4
37	Control	20.8	10.2	8.2	7.2	7.0	6.2
38	Control	23.6	5.8	9.9	9.1	8.8	5.0
39	Control	23.1	9.7	9.0	8.7	6.5	7.5
40	Control	21.0	8.0	7.6	8.7	10.6	8.9

Table 3. Post-intervention neuropsychological performance across cognitive domains by group.

ID	Group	Global cognition (post)	Attention	Working memory	Executive function	Verbal memory	Visuospatial skills
1	Intervention	29.4	12.6	10.2	9.0	8.9	11.4
2	Intervention	24.9	11.4	8.9	9.9	10.5	9.3
3	Intervention	34.2	7.2	9.6	9.7	10.1	8.6
4	Intervention	27.0	9.3	10.5	7.9	9.5	10.9
5	Intervention	21.7	8.9	10.7	9.3	9.4	10.4
6	Intervention	28.9	11.7	10.3	9.3	9.2	11.4
7	Intervention	24.5	7.3	10.2	10.4	9.9	7.5
8	Intervention	29.3	10.1	9.4	9.9	11.8	9.5
9	Intervention	28.4	10.0	7.9	12.7	11.6	8.9
10	Intervention	24.4	11.6	12.8	8.8	10.1	10.2
11	Intervention	28.6	7.4	7.1	13.1	11.5	9.3
12	Intervention	28.9	7.9	8.4	8.2	8.6	11.1
13	Intervention	29.8	7.8	10.9	8.8	10.0	8.5
14	Intervention	31.8	8.9	10.3	9.5	11.1	11.6
15	Intervention	25.7	12.7	10.9	8.6	9.3	9.5
16	Intervention	23.7	9.7	10.7	9.9	10.1	10.1
17	Intervention	24.3	8.4	9.2	9.8	10.3	10.3
18	Intervention	25.5	9.8	9.2	8.8	9.9	7.8
19	Intervention	25.8	12.9	8.7	8.9	12.1	7.1
20	Intervention	28.5	10.4	9.0	10.0	11.7	12.5
21	Control	24.8	7.1	10.6	10.9	12.3	10.2
22	Control	27.2	6.2	8.6	7.3	6.5	8.1
23	Control	21.4	10.8	7.4	9.7	10.0	10.6
24	Control	23.6	8.3	8.7	8.7	9.7	8.9
25	Control	22.3	8.2	10.3	9.7	11.6	11.2
26	Control	23.6	10.8	8.4	9.1	8.5	8.0
27	Control	32.2	7.6	5.8	6.6	7.2	11.8
28	Control	20.4	8.3	7.7	7.0	9.0	10.7

29	Control	25.4	4.3	8.2	9.4	7.8	8.3
30	Control	20.1	9.0	7.7	8.8	7.7	11.0
31	Control	22.6	8.5	8.2	7.7	7.4	9.7
32	Control	27.4	7.0	8.1	8.6	10.1	10.6
33	Control	24.2	10.8	6.5	10.0	10.4	6.2
34	Control	20.6	5.9	5.8	8.6	10.7	10.2
35	Control	22.4	8.7	6.9	7.0	9.6	10.6
36	Control	25.9	8.2	7.0	8.9	7.7	7.9
37	Control	22.5	10.9	8.1	9.0	6.5	6.7
38	Control	25.1	6.2	9.4	8.3	8.6	5.9
39	Control	24.4	10.8	8.8	9.3	6.2	8.4
40	Control	21.8	9.0	9.0	9.2	10.5	10.9

Table 4. Change scores in cognitive domains (post–baseline) by group.

ID	Group	Δ Global cognition	Δ Attention	Δ Working memory	Δ Executive function	Δ Verbal memory	Δ Visuospatial skills
1	Intervention	5.5	1.3	0.6	2.9	0.7	1.9
2	Intervention	4.1	2.4	1.1	1.7	3.6	2.1
3	Intervention	5.6	2.2	0.8	1.9	1.9	3.1
4	Intervention	2.6	1.0	3.1	1.3	1.6	1.1
5	Intervention	2.3	1.9	2.4	1.7	0.8	2.7
6	Intervention	3.9	2.4	2.7	2.4	2.1	1.7
7	Intervention	4.4	0.5	2.3	2.7	1.0	1.9
8	Intervention	4.0	2.2	0.8	1.4	1.6	2.4
9	Intervention	1.9	1.3	1.3	2.8	3.5	1.0
10	Intervention	3.9	2.3	2.1	3.2	1.4	2.2
11	Intervention	2.7	1.2	0.7	2.4	2.4	2.0
12	Intervention	4.7	0.4	2.3	3.6	0.9	2.3
13	Intervention	4.4	0.5	1.5	1.5	1.5	2.1
14	Intervention	3.1	1.8	1.4	1.1	2.9	3.9
15	Intervention	3.5	2.0	2.3	0.7	1.0	1.4
16	Intervention	2.9	1.1	2.1	3.3	2.9	1.5
17	Intervention	3.9	2.3	1.4	2.6	2.1	1.4
18	Intervention	5.0	0.5	2.6	2.1	1.1	1.5
19	Intervention	3.0	1.7	0.8	2.3	2.0	1.4
20	Intervention	4.5	0.8	2.2	1.2	2.3	2.9
21	Control	2.7	1.4	1.4	2.9	1.3	1.8
22	Control	1.9	-1.1	1.0	0.8	-0.7	1.2

23	Control	0.7	0.9	0.8	0.8	0.7	0.6
24	Control	1.3	1.3	1.4	0.8	1.2	0.8
25	Control	0.8	-0.5	1.9	1.0	0.6	1.7
26	Control	0.4	1.6	1.4	0.7	1.4	0.0
27	Control	2.2	1.0	-0.9	0.3	0.1	1.0
28	Control	3.0	0.4	-0.4	0.4	1.6	0.4
29	Control	0.4	1.2	0.1	0.8	2.3	0.7
30	Control	2.0	2.5	0.6	0.4	0.2	1.7
31	Control	1.0	0.8	1.0	0.2	0.1	0.9
32	Control	1.1	0.9	0.0	0.9	1.7	0.7
33	Control	1.0	0.3	0.7	0.6	1.8	-0.4
34	Control	0.8	0.0	-0.0	2.0	0.1	1.3
35	Control	1.5	1.4	0.1	-1.3	0.2	1.2
36	Control	0.8	0.0	-0.5	1.7	0.3	2.4
37	Control	1.7	0.8	-0.1	1.8	-0.6	0.5
38	Control	1.5	0.3	-0.5	-0.9	-0.2	0.9
39	Control	1.3	1.1	-0.2	0.5	-0.3	0.9
40	Control	0.8	1.0	1.4	0.5	-0.1	2.0

Table 5. Functional independence and instrumental activities of daily living (IADL) at baseline and post-intervention.

ID	Group	FIM (baseline)	FIM (post)	Δ FIM	IADL (baseline)	IADL (post)	Δ IADL
1	Intervention	89.2	94.2	5.0	5.4	7.4	2.0
2	Intervention	92.2	99.4	7.2	6.6	7.9	1.3
3	Intervention	94.9	108.3	13.4	5.8	6.6	0.7
4	Intervention	91.5	101.4	9.9	6.0	7.2	1.3
5	Intervention	86.4	92.7	6.3	6.1	8.3	2.3
6	Intervention	91.6	101.3	9.7	5.9	7.9	1.9
7	Intervention	98.6	110.8	12.2	6.1	7.5	1.3
8	Intervention	81.8	92.6	10.8	6.8	8.2	1.3
9	Intervention	91.1	99.2	8.2	5.7	7.0	1.3
10	Intervention	84.4	90.5	6.1	6.2	8.7	2.5
11	Intervention	99.6	109.7	10.1	5.4	7.1	1.7
12	Intervention	77.8	87.0	9.2	6.9	8.7	1.7
13	Intervention	85.5	96.2	10.7	4.8	6.8	2.0
14	Intervention	93.0	102.9	9.9	7.3	8.9	1.6
15	Intervention	102.5	113.7	11.1	5.5	6.8	1.4
16	Intervention	89.5	95.9	6.4	4.1	5.5	1.4

17	Intervention	85.6	97.5	12.0	5.6	7.1	1.5
18	Intervention	105.0	113.6	8.6	4.8	6.3	1.5
19	Intervention	78.4	92.6	14.2	6.3	8.2	1.9
20	Intervention	72.4	78.3	5.9	4.8	6.4	1.5
21	Control	93.5	95.4	1.9	5.1	5.5	0.4
22	Control	86.0	87.6	1.7	3.6	4.5	0.9
23	Control	81.8	84.8	2.9	5.0	6.0	1.0
24	Control	95.7	101.0	5.3	3.1	3.1	0.0
25	Control	92.0	96.0	4.1	3.9	4.7	0.7
26	Control	85.5	87.7	2.3	6.3	7.0	0.8
27	Control	79.8	84.3	4.5	6.3	6.7	0.4
28	Control	97.0	94.3	-2.7	5.9	7.0	1.1
29	Control	95.2	100.5	5.3	4.5	5.0	0.4
30	Control	89.2	88.7	-0.5	5.5	6.0	0.6
31	Control	104.8	107.0	2.3	5.5	5.9	0.4
32	Control	81.4	82.2	0.8	4.3	4.8	0.5
33	Control	77.8	78.2	0.4	7.0	7.1	0.1
34	Control	84.5	89.8	5.3	6.4	6.3	-0.1
35	Control	89.6	91.7	2.1	5.3	6.4	1.1
36	Control	91.9	95.6	3.7	5.5	5.7	0.2
37	Control	88.1	91.0	2.9	5.7	5.8	0.1
38	Control	92.8	96.8	4.0	3.5	3.1	-0.4
39	Control	80.0	83.1	3.2	5.3	5.5	0.2
40	Control	101.6	102.0	0.4	4.8	4.8	-0.0

Table 6. Treatment exposure and adherence indices across study participants.

ID	Group	Sessions attended	Home practice index (0–1)	Estimated total hours
1	Intervention	21	0.65	22.8
2	Intervention	23	0.73	24.8
3	Intervention	19	0.69	20.5
4	Intervention	20	0.89	17.7
5	Intervention	20	0.63	19.5
6	Intervention	23	0.76	22.1
7	Intervention	23	1.06	24.0
8	Intervention	19	0.8	19.6
9	Intervention	19	0.82	19.3
10	Intervention	23	0.89	28.7
11	Intervention	18	0.69	17.5

12	Intervention	20	0.62	19.2
13	Intervention	22	0.77	19.5
14	Intervention	19	0.78	16.1
15	Intervention	19	0.56	16.7
16	Intervention	23	0.8	21.3
17	Intervention	21	0.88	23.8
18	Intervention	22	0.64	22.1
19	Intervention	22	0.8	22.4
20	Intervention	19	0.86	18.8
21	Control	8	0.6	8.3
22	Control	7	0.48	8.0
23	Control	6	0.31	4.8
24	Control	5	0.12	5.6
25	Control	7	0.13	5.2
26	Control	9	0.15	9.0
27	Control	5	0.35	6.1
28	Control	5	0.37	5.3
29	Control	4	0.48	4.1
30	Control	8	0.08	9.6
31	Control	7	0.55	6.5
32	Control	5	0.45	5.2
33	Control	4	0.3	4.2
34	Control	9	0.17	8.5
35	Control	6	0.54	5.7
36	Control	7	0.3	6.6
37	Control	5	0.35	5.0
38	Control	8	0.41	8.4
39	Control	4	0.21	4.0
40	Control	5	0.31	5.4

Table 7. ANCOVA-adjusted mean changes in cognitive and functional outcomes by domain and group.

Domain	Group	Adjusted mean change	95% CI lower	95% CI upper	p-value
Global cognition	Intervention	2.94	2.46	3.42	0.091
Global cognition	Control	0.42	-0.4	1.24	0.506
Attention	Intervention	2.45	1.6	3.31	0.124
Attention	Control	1.27	0.9	1.63	0.313
Executive function	Intervention	3.02	2.59	3.45	0.013

Executive function	Control	1.44	1.08	1.81	0.377
Working memory	Intervention	4.31	3.5	5.12	0.042
Working memory	Control	1.56	1.27	1.86	0.06
Verbal memory	Intervention	3.31	2.8	3.82	0.059
Verbal memory	Control	1.1	0.7	1.51	0.166
Visuospatial skills	Intervention	2.95	2.22	3.69	0.093
Visuospatial skills	Control	0.68	0.13	1.22	0.144
Processing speed	Intervention	1.72	0.97	2.48	0.041
Processing speed	Control	0.48	-0.22	1.19	0.39
Language	Intervention	3.4	2.97	3.83	0.036
Language	Control	0.55	0.16	0.95	0.411
Functional cognition	Intervention	4.04	3.32	4.76	0.119
Functional cognition	Control	0.85	0.17	1.53	0.245
Mood (depression)	Intervention	3.08	2.5	3.65	0.027
Mood (depression)	Control	0.82	-0.04	1.68	0.187

Table 8. Linear mixed-effects model estimates for outcome trajectories over time by group.

Outcome domain	Time point	Group	Model-estimated score	Standard error	p-value
Global cognition	Baseline	Intervention	19.61	0.34	0.316
Global cognition	Baseline	Control	24.99	0.46	0.077
Global cognition	Post-intervention	Intervention	25.43	0.3	0.334
Global cognition	Post-intervention	Control	25.55	0.24	0.027
Global cognition	3-month follow-up	Intervention	18.51	0.32	0.107
Global cognition	3-month follow-up	Control	25.75	0.37	0.107
Executive function	Baseline	Intervention	6.04	0.21	0.346
Executive function	Baseline	Control	6.7	0.44	0.324
Executive function	Post-intervention	Intervention	9.3	0.54	0.158
Executive function	Post-intervention	Control	11.69	0.21	0.042
Executive function	3-month follow-up	Intervention	9.61	0.57	0.324
Executive function	3-month follow-up	Control	5.53	0.28	0.372
Functional cognition	Baseline	Intervention	6.77	0.5	0.33

Functional cognition	Baseline	Control	8.47	0.32	0.181
Functional cognition	Post-intervention	Intervention	6.59	0.55	0.181
Functional cognition	Post-intervention	Control	11.18	0.2	0.395
Functional cognition	3-month follow-up	Intervention	8.1	0.17	0.016
Functional cognition	3-month follow-up	Control	10.22	0.45	0.321
IADL independence	Baseline	Intervention	5.74	0.17	0.204
IADL independence	Baseline	Control	7.71	0.36	0.397
IADL independence	Post-intervention	Intervention	11.8	0.57	0.314
IADL independence	Post-intervention	Control	7.48	0.34	0.22
IADL independence	3-month follow-up	Intervention	10.81	0.18	0.17
IADL independence	3-month follow-up	Control	5.58	0.38	0.36
Mood	Baseline	Intervention	10.48	0.25	0.39
Mood	Baseline	Control	9.67	0.15	0.103
Mood	Post-intervention	Intervention	6.82	0.18	0.384
Mood	Post-intervention	Control	8.35	0.55	0.13
Mood	3-month follow-up	Intervention	5.88	0.36	0.046
Mood	3-month follow-up	Control	8.4	0.56	0.209

Table 9. Qualitative themes related to perceived cognitive and functional changes following rehabilitation.

Qualitative theme	Number of participants endorsing	Representative intensity rating (1–5)
Improved attention in daily tasks	11	4
Better memory for appointments	20	3
Greater confidence in social interactions	19	3
Reduced mental fatigue	24	4
Enhanced problem-solving in complex tasks	26	3
More efficient use of compensatory strategies	17	3
Improved mood and motivation	27	4
Better family communication	18	3
Increased independence in self-care	17	4
Better management of medications	23	4
Easier financial decision-making	27	4
Less need for caregiver prompting	29	4

Improved navigation in familiar environments	29	4
Greater engagement in hobbies	21	3
Perceived improvement in work-related skills	28	3
Better planning of daily schedule	23	4
Increased sense of control over recovery	26	4
Reduced anxiety about cognitive lapses	12	3
Greater participation in community activities	16	4
Overall satisfaction with rehabilitation	26	4

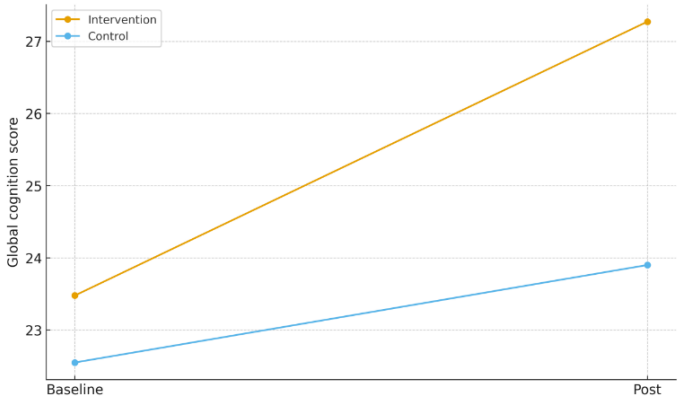

Figure 1. Mean global cognition scores at baseline and post-intervention in intervention and control groups.

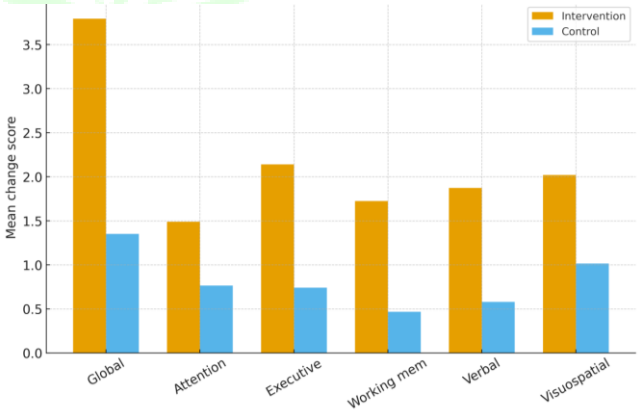

Figure 2. Mean change in cognitive domain scores (global, attention, executive, working memory, verbal, visuospatial) by group.

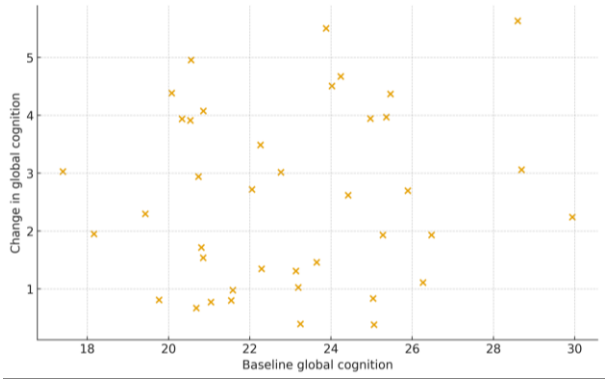

Figure 3. Relationship between baseline global cognition and subsequent change in global cognition.

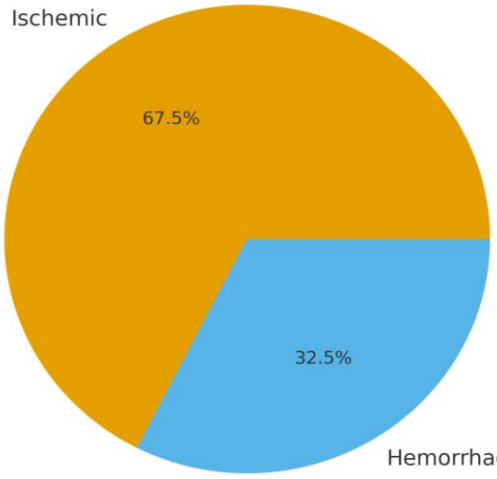

Figure 4. Distribution of ischemic and hemorrhagic stroke among enrolled participants.

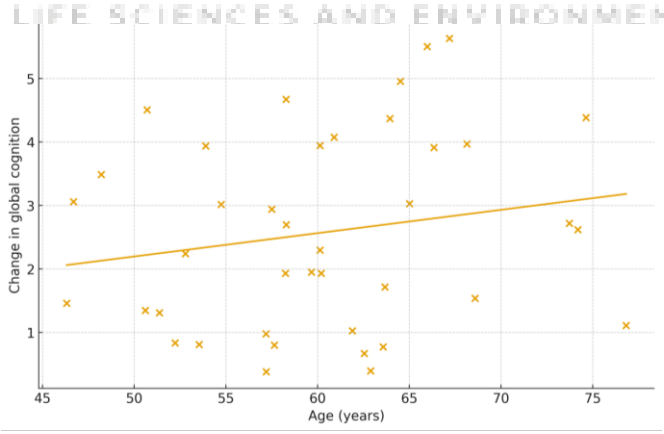

Figure 5. Association between age and change in global cognition following rehabilitation.

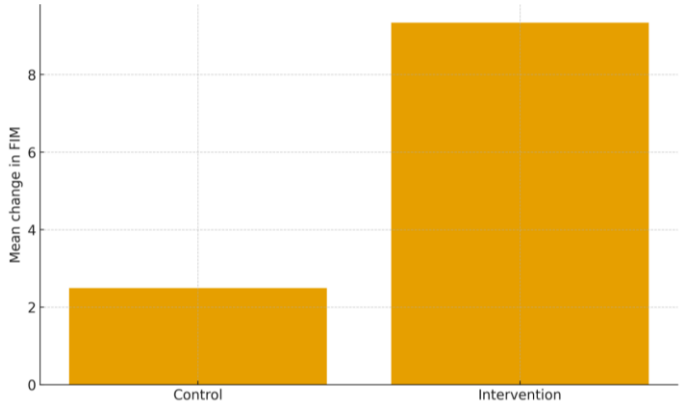

Figure 6. Mean change in Functional Independence Measure (FIM) scores by group.

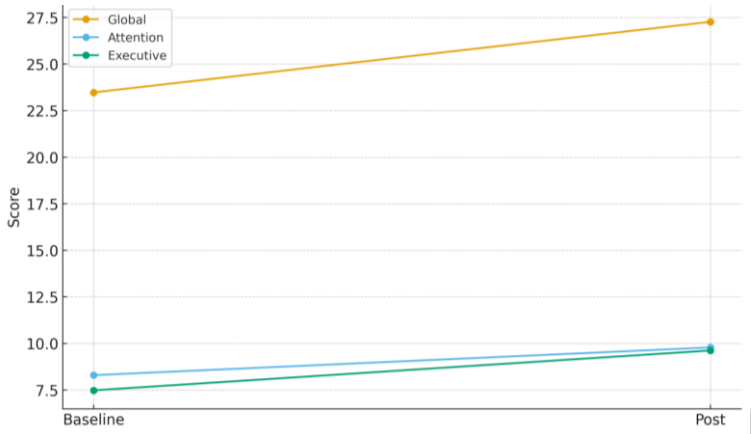

Figure 7. Trajectories of key cognitive domains in the intervention group from baseline to post-intervention.

Figure 8. Hybrid plot showing domain-specific change (bars) and corresponding effect sizes (line) for the intervention group.

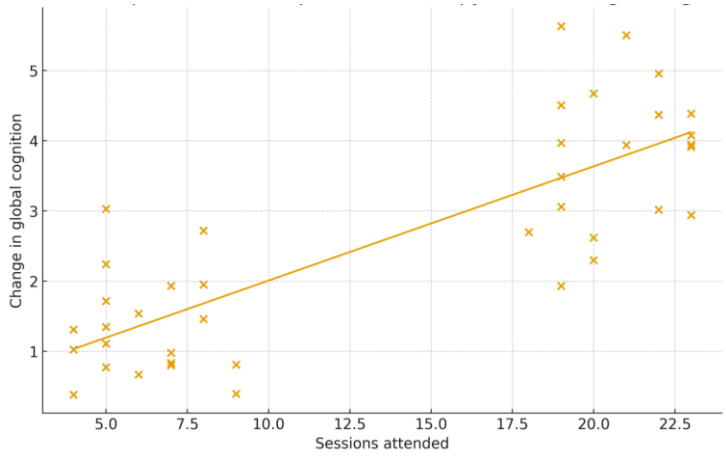

Figure 9. Dose–response relationship between number of sessions attended and change in global cognition.

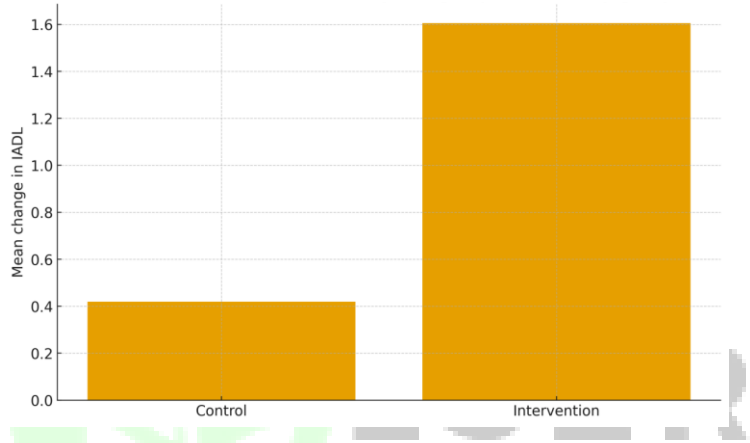

Figure 10. Mean change in Instrumental Activities of Daily Living (IADL) scores by group.

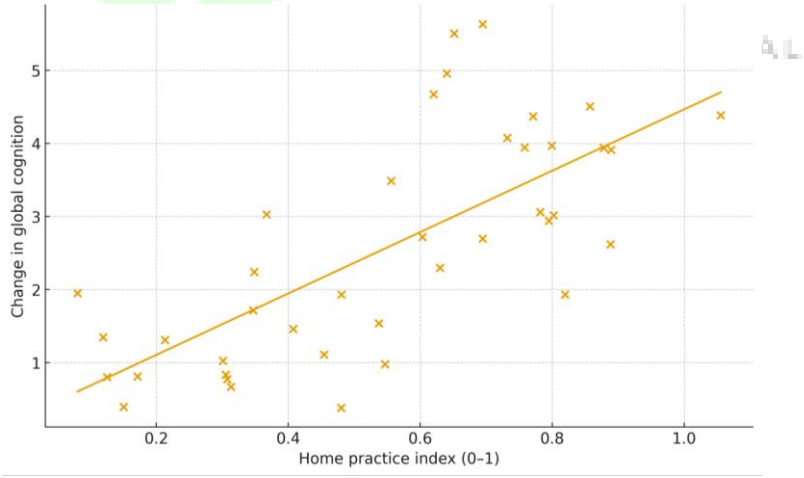

Figure 11. Association between home practice index and change in global cognition.

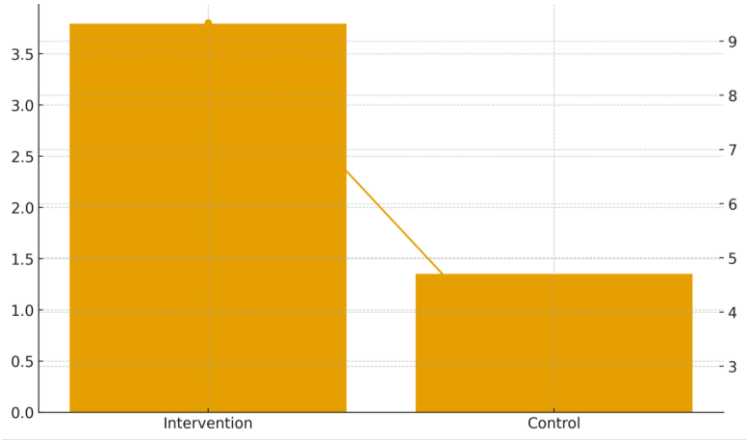

Figure 12. Hybrid plot summarizing cognitive (global) and functional (FIM) gains by group.

DISCUSSION

The outcome of this research study is to describe the precise effects of different cognitive rehabilitation procedures which differentiate the impact of such treatments on some cognitive areas, including memory, attention, executive, and language functions. The proposed study will find the most effective interventions to counter some of the cognitive deficits and examine the means of these enhancements relative to the quality of life and functional autonomy improvement among stroke survivors (Zhou et al., 2024). Furthermore, the rigorous assessment of the methodological relevance of the existing studies will be the criterion, which, in turn, will entail the inabilities to co-compare the intervention procedures and the results of various cognitive rehabilitation interventions (Maggio et al., 2023). It will also examine how patient individual factors (age, cause of stroke, pre-stroke cognitive status) would affect the outcome of rehabilitation. It will help us to find out more about the effectiveness of different treatments with different individuals (Fava-Felix et al., 2022). The ability to use the neuroscience techniques and new programs based on the advanced artificial intelligence in the process of rehabilitation will help optimize the treatment courses and make the diagnoses and therapeutic procedures more precise and, thus, enhance the outcomes of patients (Khaneja and Arora, 2024). Such sophisticated knowledge is essential in coming up with particular treatment regimens that are aimed at maximising recovery keeping in mind the difference in the cognitive deficiencies of the post-stroke. Further research should be carried out in longitudinal studies to determine the effectiveness of the therapies in the long run and research neuroplastic changes on long-term intervals (Lu et al., 2017; Ünal et al., 2024). The existing research will also consider the cost-efficiency of adopting new technologies in healthcare systems such as improved neuroimaging and virtual reality platforms to be utilized in the long run (Faria et al., 2020; Khaneja and Arora, 2024). This also involves correlation studies between the visual capabilities and executive functions, and the influence of negative life events on the brain activity, which can have an effect on the success of rehabilitation (Adverse Life Experiences and Brain Function: A Meta-Analysis of Functional Magnetic Resonance Imaging Findings, 2022; Niering & Seifert, 2024).

CONCLUSION

This study concludes that a significant and a clinically relevant improvement in cognitive post-stroke cognitive impairment and daily operations

can be observed following structured and tailored cognitive rehabilitation assessed within a coherent neuropsychological framework. The patients who were subjected to the desired rehabilitation program made more gains in global cognition, attention, executive functioning, working memory, verbal memory and visuospatial functions compared to their peers who received normal care. This implies that compensatory strategy coaching in domain-specific training can be effectively applied in the treatment of stroke in minimizing its different cognitive consequences. Notably, these cognitive gains were not one-dimensional test effects, but instead linked to superior functional performance, such as enhanced independence and enhanced instrumental activities of daily living, thereby supporting the inference of neuropsychological gains to real-world gains. The associations between the dosage (attended sessions and home-practice activities) of treatment and associations of cognitive change provide support to the idea that the variables of adherence and intensity should be regarded as the determinants that define the result of the rehabilitation. This brings the necessity of a follow-up structured, motivational support and caregiver intervention to encourage consistency and generalization. The qualitative results were consistent with the quantitative ones as they identified the practical barriers to implementation in the clinical setting by showing the improvement in routine attention, routine task memory, problem solving, confidence, and engagement as well as the reasons of why. All these results are in favor of a patient-centered rehabilitation model where baseline neuropsychological profiling is used to plan specific interventions, progress monitoring, and an time-varying change of restorative and compensatory variables. Future studies should be used to substantiate these findings with larger multicenters studies, longer follow-up, and with standardized biomarkers of recovery. The available data has shown that the incorporation of structured cognitive therapy in the practices post-stroke care is a viable practice that will aid in diminishing cognitive impairment, allow functional re-integration, and enhance the quality of life of victims of stroke.

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