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NONPHARMACOLOGICAL REHABILITATION FOR POST-STROKE COGNITIVE IMPAIRMENT: FUNCTIONAL TRANSFER AND MAINTENANCE

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Abstract: Post-stroke cognitive impairment (PSCI) can restrict independence in daily activities and social participation. Nonpharmacological interventions improve some cognitive test scores, but these gains do not consistently extend to everyday functioning or persist after treatment. This narrative review draws on a structured search of six Chinese- and English-language databases through June 30, 2026, prioritizing systematic reviews, randomized controlled trials, and guidelines. We examine cognitive, activity, and participation outcomes, distinguishing transfer to untrained tasks or settings from maintenance after intervention. Restorative and computerized cognitive training show the clearest benefits on trained tasks and closely related cognitive tests. Goal-directed rehabilitation, metacognitive strategies, and task practice address daily activities more directly, although their benefits remain outcome-specific and do not establish broad transfer. Cognitive-motor training, virtual reality, brain stimulation, and music may support rehabilitation, but improved cognition alone does not demonstrate better instrumental activities or participation. Patient characteristics, training design, and family and community support may affect whether gains are used and sustained. Small samples, varied interventions, inconsistent functional measures, and short follow-up limit interpretation. Rehabilitation should connect cognitive training and compensatory strategies with meaningful daily tasks, while assessing untrained activities, participation, and maintenance after training ends.
Keywords: Post-stroke cognitive impairment; Cognitive rehabilitation; Nonpharmacological interventions; Activities of daily living; Functional transfer; Social participation; Maintenance of benefits

1 INTRODUCTION

Post-stroke cognitive impairment (PSCI) refers broadly to cognitive impairment after a confirmed ischemic or hemorrhagic stroke, ranging from mild impairment to post-stroke dementia [1]. The affected domains, onset, and course vary with lesion location and extent, pre-stroke cognitive reserve, cerebral small vessel disease or neurodegenerative changes, recurrent stroke, and comorbidities [1-2]. Attention, executive function, information processing speed, memory, language, and visuospatial function may be affected alone or in combination [1-2]. These difficulties matter beyond cognitive testing. They can make it harder for patients to understand and follow rehabilitation plans and increase dependence on family members and caregivers for basic activities of daily living (BADL), including eating, dressing, bathing, and toileting [1, 3]. Instrumental activities of daily living (IADL), such as managing medications and finances, shopping, preparing meals, using communication devices, and traveling in the community, require memory, attention, planning, and problem-solving skills to work together. Cognitive difficulties may therefore become more apparent after discharge, when patients resume these activities [3-4]. A systematic review found consistent associations between global and domain-specific cognition and post-stroke BADL, IADL, and participation outcomes. More severe impairment was generally associated with greater difficulty completing complex tasks and returning to work, social, and leisure activities [3].

The International Classification of Functioning, Disability and Health (ICF) defines activity as performing a task or action; BADL and IADL largely fall within this domain [3, 5]. Participation concerns involvement in life situations, including family life, work, social relationships, and community activities [5]. Quality of life is different: it reflects patients' subjective assessment of their physical health, psychological state, relationships, and living environment, even though activity and participation influence that assessment [6]. These outcomes are related, but one cannot substitute for another [5-6]. Rehabilitation should assess cognitive change alongside patients' ability to complete daily tasks independently and resume social roles, while considering what the changes mean to patients and families [7-8].

Nonpharmacological approaches to PSCI include restorative and computerized cognitive training, functional cognitive rehabilitation, metacognitive strategies, and task-oriented occupational therapy [9-10]. Combined physical and cognitive training, virtual reality and other digital formats, music, mind-body exercise, and noninvasive brain stimulation are also increasingly used. The latter includes transcranial direct current stimulation and repetitive transcranial magnetic stimulation [1, 10]. Studies report gains in global cognition, individual cognitive domains, and some basic daily activities, but improvement at one level does not necessarily coincide with improvement at another [11-13]. Most trials use cognitive tests and basic self-care scales; fewer directly assess complex IADL, social participation, or sustained performance at home and in the community [13].

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The clinical questions are therefore specific: which cognitive gains affect everyday life, which training components help patients complete real tasks, and do these changes last? Existing reviews mainly address PSCI epidemiology, diagnosis, and management, or evaluate individual interventions [2, 13-14]. Systematic reviews and network meta-analyses have also compared cognitive and ADL outcomes across nonpharmacological approaches [15-16]. Their limited coverage of IADL and participation, difficulty separating trained-task gains from transfer, and sparse follow-up leave these questions unresolved [2, 13-14]. Using the ICF framework, this review examines how treatment goals, training content, and settings relate to cognitive recovery, compensatory strategy use, and functional gains. We compare transfer across tasks and settings and maintenance after training, then consider patient characteristics, intervention design, and family and community support. The aim is to guide rehabilitation choices and outcome assessment around patients' everyday goals.

2 LITERATURE REVIEW: FUNCTIONAL GAINS, TRANSFER, AND MAINTENANCE

We use functional gains to mean improvements in daily task performance, independence, or participation, including directly trained activities. Functional transfer has a narrower meaning: benefits extend to an untrained task or a new setting [17-18]. A change in cognitive test scores alone establishes neither. Cognitive assessment should therefore be accompanied by measures of activities of daily living (ADL), including BADL and IADL, to determine whether an intervention improves daily functioning [13, 19].

Trained-task improvement, near cognitive transfer, far cognitive transfer, and real-world functional transfer answer different questions [17, 20]. Near transfer concerns untrained cognitive tasks similar in structure to the practiced task. Far transfer concerns tasks with substantially different structures or other cognitive domains [17, 20]. Functional transfer requires improvement in daily activities that were not directly trained, or in new settings [13, 19]. Maintenance adds a separate time dimension: are the benefits still present after the intervention ends? Its assessment must specify the follow-up interval and any continued practice or support. Figure 1 shows these distinctions.

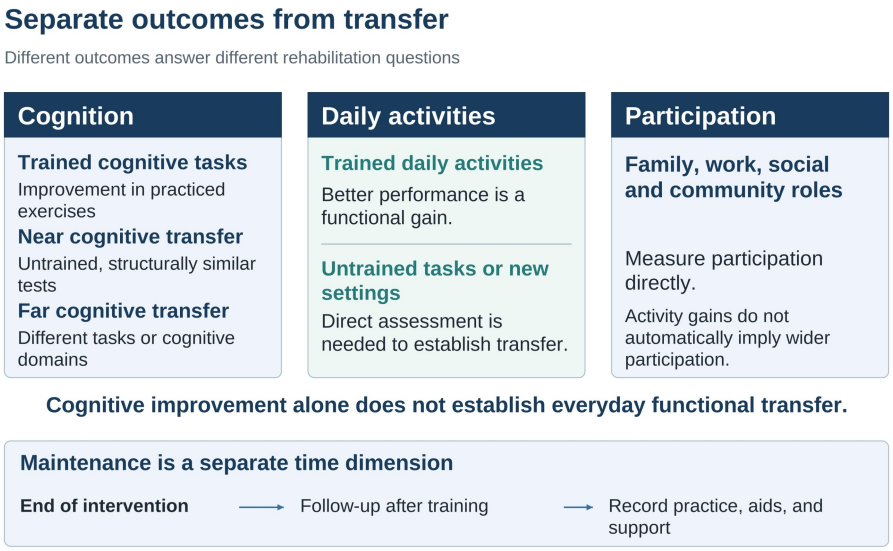


Figure 1 Cognitive Gains, Functional Transfer, and Maintenance

Note: Improvements on trained cognitive tasks, near and far cognitive transfer, daily activities, and participation are separate outcomes. Better performance on a directly trained daily activity is a functional gain but does not alone demonstrate transfer. Transfer requires assessment of untrained tasks or new settings. Maintenance is assessed after intervention cessation, with the follow-up interval and continued practice, aids, and support recorded [5, 13, 17, 19-20]. The layout does not imply a fixed sequence or a causal pathway. Abbreviations: BADL, basic activities of daily living; IADL, instrumental activities of daily living.

Restorative cognitive retraining can improve some cognitive measures, but consistent gains in BADL, IADL, and other functional outcomes have not been demonstrated [13, 18]. Working-memory and other computerized training likewise tend to improve trained tasks or similar cognitive tests, without consistent gains in daily activities or social participation [19-20]. One possible explanation is the distance between training and everyday demands. An exercise may isolate one cognitive process under fixed rules. Managing medication, shopping, preparing meals, or traveling in the community instead requires attention, memory, executive function, and problem solving in changing, less structured settings. Patients must also coordinate movement and communication, manage emotions, and use the resources available to them [3, 8, 21].

Cognitive gains may be more useful when patients learn transferable strategies, apply them to specific activities, and continue practicing in everyday settings after formal training ends. Goals should reflect activities that matter to the patient. Guided discovery, self-monitoring, and problem-solving practice can help patients select a strategy, judge whether it works, and adjust it across tasks [12, 22]. Schedules, smartphone reminders, and step-by-step checklists can

support patients who cannot yet complete a task independently. As ability improves, therapist or caregiver prompts can be reduced to encourage independent performance [8, 13]. Practice should extend across the therapy room, home, and community, with home exercises, caregiver support, and community rehabilitation helping to connect training with daily routines [17, 22-23]. The extent of transfer and maintenance also depends on impairment type and severity, stroke phase, training timing and dose, motivation, and the family and community environment [1, 8, 23].

The following sections examine each intervention's goals and training content alongside cognitive and functional outcomes, transfer across tasks and settings, and maintenance after training.

3 METHODOLOGY: REVIEW APPROACH

We used a structured literature search to support this narrative review. Sources included full-text publications collected by the authors and searches of PubMed/MEDLINE, Web of Science Core Collection, Embase, the Cochrane Library, China National Knowledge Infrastructure (CNKI), and Wanfang, from inception to June 30, 2026. We also checked reference lists and forward citations of key systematic reviews, guidelines, scientific statements, and trials. Conference abstracts and unpublished gray literature were not searched systematically. No systematic review protocol was registered, and no new meta-analysis was performed.

Searches combined subject headings and free-text terms for stroke, post-stroke cognitive impairment or cognitive dysfunction, nonpharmacological rehabilitation, and functional outcomes. Intervention terms covered cognitive rehabilitation, computerized training, occupational therapy, metacognitive and compensatory strategies, task-specific training, exercise, dual-task training, virtual reality, digital rehabilitation, noninvasive brain stimulation, and music. Outcome terms included daily activities, participation, transfer, generalization, quality of life, and caregiver burden. We used Medical Subject Headings in PubMed and adapted search fields and syntax for the other databases.

We included publications that evaluated nonpharmacological interventions in adults with cognitive impairment after ischemic or hemorrhagic stroke, examined links between cognition and post-stroke functional outcomes, or offered relevant clinical or methodological guidance. Randomized trials, systematic reviews, and meta-analyses were prioritized; observational studies, guidelines, and scientific statements provided context. Studies of mixed causes of cognitive impairment were considered when stroke-specific results were available, or when stroke accounted for at least half of the sample and the findings could be interpreted for this population. We excluded pediatric studies, drug-only interventions, case reports, protocols without results, conference abstracts, duplicate publications, and reports without accessible full text. Studies of isolated motor, language, or perceptual impairments were included only when they also reported relevant cognitive, activity, or participation outcomes.

After removing duplicates, we screened titles and abstracts and assessed full texts against these criteria. Reports from the same study were considered together, not as independent evidence. We organized information by design, population, stroke phase, intervention components and dose, comparator, outcome domain, assessment method, and follow-up timing. Systematic reviews informed the overall synthesis; selected trials showed how training content related to the outcomes measured. We distinguished trained-task gains from transfer to untrained tasks or settings and from maintenance after intervention. Follow-up findings were interpreted with attention to continued practice, assistive aids, and caregiver support.

Methodological limitations were discussed qualitatively, focusing on comparators, dose matching, outcome measures, and follow-up. We did not calculate new pooled estimates or assign formal certainty ratings. Any certainty ratings cited are those of the original reviews. The Scale for the Assessment of Narrative Review Articles (SANRA) guided the presentation of the review question, search methods, references, scientific reasoning, and outcomes [24]. The evidence tables describe the findings rather than rank interventions.

4 RESULTS: NARRATIVE SYNTHESIS OF NONPHARMACOLOGICAL INTERVENTIONS

4.1 Restorative and Computerized Cognitive Training

Restorative cognitive training uses repeated, structured exercises of increasing difficulty to train attention, memory, working memory, executive function, and processing speed [13]. Gains occur more often on practiced tasks and closely related cognitive tests than in everyday activities [13, 25]. Attention process training, for example, improved its main attention outcome but did not consistently outperform the comparator on other attention measures or broader outcomes [26]. A meta-analysis found no clear between-group benefit of restorative retraining for BADL, IADL, or other functional measures. The standardized mean difference for IADL was -0.19 (95% confidence interval, -0.65 to 0.27) [13]. Improvement within a cognitive domain should not, on this evidence, be treated as proof of daily-life transfer.

Computerized cognitive training provides repeated practice with adaptive difficulty and immediate feedback through standardized platforms [20, 25]. Reviews report improvements in global cognition, attention, and executive function, and possible benefits for quality of life. Programs nevertheless differ in software, training content, and frequency [25]. Functional findings are sensitive to study design and the measures selected. Earlier studies reported gains on the Barthel Index, modified Barthel Index, or Functional Independence Measure, but incomplete descriptions of randomization, allocation concealment, and blinding limit confidence in those findings [27].

In an active-control study, improvements were concentrated on working-memory and processing-speed tests similar to the trained content, without clear changes in quality of life or subjective cognitive difficulties [28]. Home-based adaptive training and computerized training in chronic stroke improved selected cognitive domains, but BADL, IADL,

everyday activity, and participation gains were inconsistent [20, 29]. Adaptive working-memory training did not outperform nonadaptive training on overall IADL [19]. A RehaCom trial similarly found cognitive gains without a significant between-group difference in ADL [30].

The clearest benefits of restorative and computerized training remain those on trained tasks and closely related cognitive outcomes, rather than complex activities or participation [13, 19, 25]. Some recent studies have reported higher modified Barthel Index scores [31]. This scale mainly measures basic self-care and mobility, however, so a better score does not establish transfer to medication management, shopping, meal preparation, finances, or community travel. Cognitive training may prepare patients for strategy use and task learning, but the evidence does not support treating it as a complete functional rehabilitation program on its own [13, 31].

4.2 Compensatory, Metacognitive, and Knowledge Acquisition Interventions

Compensatory interventions help patients manage persistent cognitive difficulties rather than directly restore the impaired function. Calendars, task lists, pill organizers, electronic reminders, step cards, and environmental cues provide external support for everyday activities [8, 13]. Metacognitive training teaches patients to recognize and manage their difficulties by setting goals, planning tasks, monitoring performance, checking results, identifying errors, and adjusting strategies [22]. Knowledge acquisition approaches have a more specific aim: learning the information and procedures needed for a particular daily task. They use methods such as errorless learning, cue fading, and spaced retrieval, rather than seeking general cognitive recovery [13]. All these approaches change how a task is completed without requiring broad restoration of cognition [13]. High-quality randomized evidence for external aids, errorless learning, and cue fading in PSCI remains sparse, so the independent functional contribution of each technique is not yet clear [10, 18].

Guided strategy training provides some of the more direct trial evidence. In a pilot randomized trial of 43 patients with acute stroke and cognitive impairment, direct skill training and guided training were dose-matched. Direct training produced greater gains in functional independence at discharge, while guided training produced greater gains at the 3-, 6-, and 12-month assessments. The between-group difference in change at 12 months was 10.57 points [22]. The later advantage suggests that learning to identify problems and develop strategies may support recovery beyond discharge, although the finding needs confirmation in a larger trial [22].

The community-based OPASS multicenter trial compared participation-oriented strategy training with a dose-matched attention control in 195 stroke survivors with executive dysfunction [12]. The strategy group did better on productive and social participation, but not on other activities, global cognition, or self-efficacy. The participation advantages were no longer evident at 3 months [12]. Thus, targeting participation goals yielded short-term benefits in the measured participation outcomes, without clear evidence of broader functional transfer or sustained benefit [12].

4.3 Occupation-, Task-, and Participation-Oriented Rehabilitation

Occupation-, task-, and participation-oriented rehabilitation begins with activities the patient wants to resume. Activity analysis, task breakdown, compensatory strategies, environmental changes, and repeated practice are applied to dressing, taking medication, preparing meals, shopping, managing finances, using a mobile phone, and community travel [8, 22]. The American Heart Association/American Stroke Association (AHA/ASA) guidelines recommend repetitive, graded task-specific training that becomes more difficult as ability improves, taking account of the expected discharge setting. They also recommend individualized ADL and IADL training [8]. These recommendations concern stroke rehabilitation generally, not evidence specific to PSCI [8]. In the review by O'Donoghue et al., interventions classified as occupation-oriented did not improve cognition more than usual care. Intervention content, outcomes, and risk of bias varied substantially between studies [10].

A randomized trial of 20 patients with chronic stroke added restorative exercises and multicontext cognitive rehabilitation to usual physiotherapy [32]. At 8 weeks, the intervention group had better global cognition and patient-rated occupational performance and satisfaction than the control group. Functional independence and social participation, however, did not differ significantly between groups [32]. The trial supports combining cognitive exercises, strategy use, and patient-selected activities, while showing why gains in target activities must be assessed separately from overall independence and participation.

A nationwide Danish survey found that occupational therapists often combined restorative and knowledge acquisition approaches in hospital wards, bathrooms, and patients' homes, using assistive devices and involving family members. Only about half used standardized assessments. Standardized tools for evaluating intervention outcomes were used by approximately 32% of hospital therapists and 40% of those in community services. Training frequency, session length, and overall duration also varied markedly by setting [33]. Assessment should therefore focus on how well patients complete target tasks, the errors they make, the prompts they need, and their performance on untrained tasks at home and in the community, rather than rely solely on the Montreal Cognitive Assessment (MoCA) or Barthel-based scales [8, 33]. More than half of patients described as having made a "good recovery" on conventional activity scales have been reported to retain cognitive impairment and difficulties with social reintegration [34]. Because occupation-, task-, and participation-oriented rehabilitation closely resembles the intended daily activities, it may offer a more direct route for applying cognitive strategies. That remains a theoretical advantage rather than an established general effect [21-22, 32].

4.4 Cognitive-Motor Integration

Exercise can improve cardiorespiratory and motor reserve and may support cognitive recovery through cerebral blood flow, metabolic support, and neuroplasticity [10, 35]. In a randomized trial of 48 patients with PSCI, 24 weeks of Baduanjin improved global cognition, executive function, memory, and attention. A between-group difference in modified Barthel Index scores reached statistical significance 4 weeks after training ended [36]. Only 41 participants completed assessment, and the functional measures were limited to basic ADL, so larger studies are needed to confirm the result [36]. Another approach combines exercise and cognitive training sequentially. Among 225 patients with stroke and vascular cognitive impairment, sequential training improved executive function, attention, working memory, and mental rotation more than exercise alone, cognitive training alone, or control. The combined group remained above baseline on all four cognitive tests at 6 months [35]. ADL and participation were not measured, leaving the daily-life relevance of these sustained cognitive gains unresolved [35].

Cognitive-motor dual-task training, unlike sequential training, places cognitive and motor demands on the patient at the same time. It may more closely reflect activities such as walking while talking, watching traffic, carrying objects, or maintaining balance amid distractions [37-38]. Evidence of functional benefit is less developed than evidence of cognitive change. In a trial of 20 patients with subacute stroke, some balance and cognitive measures improved within groups, but changes in cognition, motor function, and ADL did not differ significantly between groups [37]. Another PSCI trial found better Mini-Mental State Examination (MMSE) and MoCA scores, shorter P300 latency, and an earlier peak in frontal oxygenated hemoglobin after dual-task training. It did not assess ADL, IADL, or participation [39]. The physiological findings may help explain a cognitive effect, but do not show that daily functioning improved.

A three-group trial compared simultaneous training, sequential training, and an active control. Of 39 enrolled participants, 29 completed training. Conventional between-group tests did not establish clear differences in IADL or caregiver burden, although exploratory analyses suggested broader responses across domains with simultaneous training [40]. A systematic review of 14 randomized trials found a small pooled cognitive benefit from cognitive-motor dual-task training after stroke, with benefits persisting during post-intervention follow-up [41].

Cognitive-motor integration may help connect cognitive and motor abilities with the demands of complex activities, but far transfer has not been established. To test that link, studies need controls matched for total training dose and treatment contact time. Dual-task cost, IADL, community activities, social participation, and maintenance after training should be core outcomes, not inferred from improved cognitive or motor scores [23, 37, 40].

4.5 Virtual Reality and Context-Based Digital Rehabilitation

Virtual reality can simulate kitchen, supermarket, urban, and traffic-related tasks in a safe, controlled setting. Multistep activities can train memory, attention, visuospatial function, and executive function together, with immediate feedback and adjustable difficulty [21, 42-43]. A 2022 meta-analysis of 21 randomized trials involving 1,149 patients with PSCI reported improvements in global cognition, selected cognitive domains, and function measured with the Barthel Index, modified Barthel Index, and Functional Independence Measure [11].

Resembling everyday life is not the same as demonstrating transfer to it [21, 43]. Reh@City trains several cognitive domains through everyday tasks in a virtual city. Compared with conventional cognitive training of equal duration, it produced greater gains in global cognition, attention, and executive function. No clear advantage was found in ADL or other functional domains of the Stroke Impact Scale, and objective task performance at home or in the community was not assessed [21]. A single-group study reported short-term cognitive gains after 6 to 10 sessions of virtual daily-life tasks, but could not separate training effects from spontaneous recovery or repeated testing [44]. The immersive VIRTUE trial mainly examined safety, acceptability, and trends in treatment effects; it did not establish long-term functional effectiveness [42]. Virtual reality can make training tasks more similar to daily activities, but better virtual-task performance or Barthel-based scores alone do not demonstrate far transfer to everyday life [21, 43].

Digital programs also differ in what patients practice. Computer game-assisted task-specific exercises, for example, combine motor practice with cognitive demands [45]. Their effects need to be considered in relation to task goals, training dose, and the comparator, rather than attributed to the digital platform alone.

4.6 Noninvasive Brain Stimulation

Transcranial direct current stimulation (tDCS), repetitive transcranial magnetic stimulation (rTMS), and intermittent theta-burst stimulation (iTBS) modulate cortical excitability and network plasticity. PSCI studies therefore often combine them with cognitive training [46-48]. A meta-analysis of 11 randomized trials with 663 patients found that tDCS plus cognitive rehabilitation improved MoCA, MMSE, and Loewenstein Occupational Therapy Cognitive Assessment (LOTCA) scores, ADL outcomes, and modified Barthel Index scores [47]. The pooled MoCA, ADL, and modified Barthel Index findings were highly heterogeneous, and studies differed in stimulation intensity and targets, lesion characteristics, and cognitive training [47]. In a four-group trial of 72 participants, computer-assisted training plus tDCS was associated with more favorable MoCA and cerebrovascular reactivity results. The trial did not establish that combined treatment improved IADL more than every single-intervention group [49].

A meta-analysis of eight trials involving 336 participants suggested short-term benefits of rTMS plus cognitive training for global cognition, executive function, working memory, and ADL, but not clearly for memory or attention [46]. Evidence certainty was low or very low for most outcomes under the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework, and long-term cognitive and functional evidence was lacking [46].

In a sham-controlled trial of left dorsolateral prefrontal iTBS plus cognitive training, 72 patients enrolled and 69 completed 4 weeks. MMSE, MoCA, digit span, and Barthel Index scores improved more with active iTBS. The small trial used no individualized stimulation parameters, cognitive subtype stratification, or long-term follow-up [48]. Another trial assigned 45 patients with PSCI to iTBS, rTMS, or sham stimulation alongside the same cognitive training. Both active groups improved MoCA scores more than sham after 10 days [50].

The evidence is stronger for brain stimulation as an adjunct to active cognitive training than for independent restoration of complex daily skills [46, 49]. Whether stimulation delivered alongside goal-directed strategy and task training improves far transfer remains to be tested.

4.7 Music Listening Interventions

Music listening can engage networks involved in attention, memory, language, and emotion regulation and places relatively few demands on patients. It can be continued in hospital or at home [51-52]. An early single-blind, three-arm trial assigned 60 patients with acute middle cerebral artery stroke to self-selected music, audiobooks, or no listening materials. Daily music listening continued for 2 months. Compared with the other groups, the music group showed better recovery of verbal memory and focused attention, and less depressed mood at the end of treatment [52]. This suggests that an enriched auditory environment may support early cognitive recovery, but it does not establish gains in complex IADL or social participation [52].

A PSCI trial compared 3 months of individualized music listening with white noise. Playlists reflected patients' preferences, cultural backgrounds, and life experiences [51]. The music group had more favorable MoCA, delayed recall, orientation, National Institutes of Health Stroke Scale (NIHSS), and Barthel Index results, along with lower caregiver burden. Changes in anxiety and depression did not differ significantly between groups, and no intervention-related adverse effects were reported [51]. Only 34 participants completed the study. With outcomes largely confined to global cognition, basic ADL, and caregiver reports, it cannot establish that music independently improves complex activities or long-term participation [51]. Music is better regarded as a low-burden addition for cognitive stimulation and participation support than as a substitute for structured cognitive and functional training.

Table 1 compares cognitive findings, functional outcomes, and follow-up results from selected controlled trials.

Table 1 Cognitive and Functional Outcomes in Selected Controlled Trials

Study and sample	Intervention comparison	Cognitive findings	Functional findings	Follow-up and interpretation
Skidmore et al. [22] 43 participants; acute stroke with cognitive impairment	Dose-matched guided strategy training vs direct skill training, both added to usual care	The principal outcome was functional independence, rather than a claim of global cognitive restoration.	Direct training favored discharge gains; guided training favored later FIM change. The difference in 12-month change was 10.57 points.	Assessments at 3, 6, and 12 months. Later functional advantage does not establish cognitive mediation.
Hsu et al. [12] (OPASS) 195 community-dwelling stroke survivors with executive dysfunction	Participation-oriented strategy training vs dose-matched attention control	No between-group improvement in global cognition.	Short-term advantages in productive and social participation; no advantage in other activities or self-efficacy.	Participation advantages were no longer evident at 3 months. Benefits were outcome-specific and not maintained.
Erkan Oğul et al. [32] 20 participants; chronic stroke	Multicontext cognitive rehabilitation plus restorative exercises and physiotherapy vs physiotherapy	Better global cognitive performance after 8 weeks.	Better patient-rated occupational performance and satisfaction; no significant difference in functional independence or participation.	End-of-treatment assessment. Target-activity gains should not be equated with broad independence or participation gains.
B. Wang et al. [35] 225 participants with stroke and vascular cognitive impairment	Sequential exercise plus cognitive training vs either component alone or control	Greater improvement in executive function, attention, working memory, and mental rotation.	ADL and participation were not assessed.	At 6 months, the combined group remained above baseline on four tests. Cognitive maintenance does not establish functional transfer; total doses differed.
Zheng et al. [36] 48 randomized; 41 completed assessments	24-week Baduanjin program vs control	Improvements in global cognition, executive function, memory, and attention.	A between-group difference in modified Barthel Index was evident 4 weeks after training.	4-week post-intervention follow-up. Evidence concerns basic ADL, not complex IADL or participation.

Study and sample	Intervention comparison	Cognitive findings	Functional findings	Follow-up and interpretation
Liu et al. [40] 39 enrolled; 29 completed training	Simultaneous vs sequential exercise-cognitive training vs active control	Exploratory analyses suggested broader responses with simultaneous training.	Conventional between-group tests did not establish clear IADL or caregiver-burden differences.	Exploratory multidomain patterns are not confirmatory evidence of broad functional transfer.
Xia et al. [48] 72 enrolled; 69 completed	Left prefrontal iTBS plus cognitive training vs sham plus cognitive training	Greater MMSE, MoCA, and digit-span gains after 4 weeks.	Greater Barthel Index improvement.	No long-term follow-up. Basic ADL improvement does not demonstrate transfer to complex daily activities.
Han et al. [50] 45 participants with PSCI	iTBS or rTMS plus cognitive training vs sham plus cognitive training	Both active protocols improved MoCA more than sham after 10 days.	ADL, IADL, and participation were not evaluated.	End-of-treatment cognitive effects do not establish functional transfer or maintenance.

Note: Selected studies illustrate differences between cognitive and functional outcomes; this is not an exhaustive trial inventory, an intervention ranking, or a new risk-of-bias assessment. Sample sizes distinguish enrollment from completion where reported. Follow-up anchors are retained as reported rather than assumed to be identical across studies. Abbreviations: ADL, activities of daily living; FIM, Functional Independence Measure; IADL, instrumental activities of daily living; iTBS, intermittent theta-burst stimulation; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; PSCI, post-stroke cognitive impairment; rTMS, repetitive transcranial magnetic stimulation.

5 DISCUSSION

Across interventions, cognitive, activity, and participation outcomes often diverge. The useful comparison is not which technique produces the largest MoCA or MMSE change, but where its benefits are seen, how the treatment approaches the problem, and whether those benefits persist after training [12-13].

5.1 Bottom-Up and Top-Down Approaches

We use two broad treatment approaches to interpret these differences. They draw on restorative, compensatory, and knowledge acquisition models of cognitive rehabilitation, and on the distinction between bottom-up treatment of impairments and top-down work on goals and strategies in stroke rehabilitation [12-13].

Bottom-up approaches target cognitive or motor impairments through restorative or computerized training, physical activity, or training combined with brain stimulation. They aim to strengthen the abilities needed for attention, executive control, working memory, learning, and movement [13, 25, 35, 46]. Most evidence concerns impairment-level changes and some near cognitive transfer. Direct benefits for complex IADL and participation remain less clear. These approaches may therefore support the abilities needed for subsequent strategy use and task learning, rather than deliver those functional outcomes on their own [13, 20].

Top-down approaches begin with everyday activities and social roles. Patients work on identifying problems, setting goals, developing strategies, using compensatory aids, learning specific knowledge or skills, and practicing real tasks [12-13, 22]. Compensatory and knowledge acquisition methods draw on preserved abilities, external support, and structured learning to help complete a particular task. Guided and participation-oriented training instead emphasizes the patient's role in recognizing a barrier, developing a solution, and applying that problem-solving process in a new situation [12-13, 22]. Some trials report changes in independence or particular participation outcomes without corresponding between-group changes in global cognition. Without mediation analyses or process evaluations, however, this does not establish that top-down treatment produces stable functional effects independently of cognitive change [12, 23].

Virtual reality and cognitive-motor dual-task training are task formats, not inherently bottom-up or top-down treatments. Either can deliver repetitive cognitive exercises or simulate multistep activities and competing task demands [21, 37, 43]. Greater relevance to everyday situations, more practice opportunities, and continued use may support generalization and maintenance. Realistic training still needs to be followed by direct assessment of untrained daily tasks and participation; realism alone is not evidence of transfer [21, 23, 43].

The two approaches can be combined concurrently, sequentially, or in phases to address limitations in cognitive and motor abilities, strategy use, task practice, and continuing support. No arrangement has yet been shown to produce the best daily-life transfer [23, 35, 40]. Larger cognitive effects in some combined programs are difficult to interpret because total training time, treatment contact, and concurrent rehabilitation also differ. Such comparisons cannot readily separate complementary components from extra training dose or a true synergistic effect [35, 40]. We therefore propose linking support for basic abilities, strategy teaching, tasks practiced in context, real-life practice, and maintenance support as a program theory to test, not a standardized sequence of care. Dose-matched comparisons, factorial designs, mediation analyses, and long-term real-world outcomes are needed to test it [23, 53].

Figure 2 organizes these components around patient-selected daily activities. It does not prescribe an order or assume that combining components produces synergy.

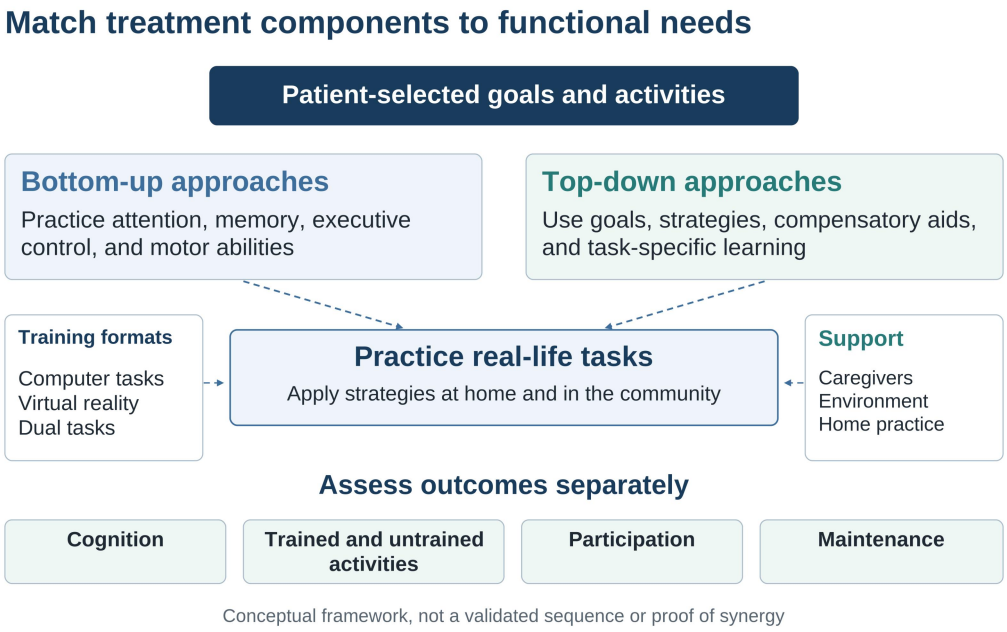


Figure 2 Combining Intervention Components Around Meaningful Daily Activities

Note: Bottom-up approaches target cognitive or motor abilities, while top-down approaches target goals, strategies, and task performance. Delivery formats and environmental support can serve either approach. Components can be combined concurrently or sequentially according to patient needs; the arrangement shown is a conceptual framework, not a validated treatment algorithm or proof of synergy [8, 12-13, 21-23, 35, 40, 53]. Outcomes and maintenance require direct assessment.

5.2 Matching Intervention Design to Patient Needs

Individualization starts with the patient's cognitive profile and what happens during the target activity. Errors, missed steps, prompting needs, and attempts at self-correction help identify the support required [8, 22]. The choice of training should also reflect preserved abilities, the main cognitive impairments, stroke phase, and motor, language, and sensory function. Some difficulties call for practice of underlying abilities; others may be addressed through strategies, aids, or changes to the task [1, 8]. This makes individualization a choice about training tools, task complexity, and assistance, not simply a grouping of patients by total cognitive scores.

5.3 Maintaining Functional Gains and Continuing Rehabilitation

A benefit at the end of treatment may not describe what happens afterward. In the guided-training trial, differences in functional independence emerged gradually after discharge, suggesting that strategy and task learning should be judged against later everyday performance [22]. OPASS showed the opposite time pattern: participation advantages present at treatment completion were no longer detected at 3 months [12]. Immediate benefit and maintenance therefore need separate assessment. Maintenance should be planned from the start, including the activities in which patients will keep using strategies and skills, the support available, and how follow-up guidance will continue.

H. Feng et al. provide one example of continuing hospital-based training at home. Nurses delivered training to patients with vascular cognitive impairment without dementia during hospitalization. Trained family caregivers then continued it after discharge using supplied materials, with telephone follow-up [54]. This arrangement connects professional input with caregiver support. In a function-focused program, the same planning can specify the daily activities to practice, the assistance needed, and the feedback patients and caregivers should receive [23, 33].

Caregivers should help patients use strategies and complete activities without taking over unnecessarily. Prompts can be given when needed, while leaving time for patients to attempt a step, check it, and correct errors. Assistance can be reduced for steps already completed independently. Schedules, task lists, and electronic reminders may still be needed where memory or executive difficulties persist [8, 22].

5.4 Limitations and Generalizability of the Current Evidence

The clinical diversity of PSCI limits how widely study findings can be applied. Age, education, cognitive reserve, pre-stroke cognition, lesion location and extent, stroke severity, small vessel disease, and neurodegenerative changes may affect patients' ability to take part in training, learn strategies, and use them outside therapy. Motor and language function, vision, mood, and fatigue add to these differences [1-2, 4]. Yet many trials are small and exclude severe aphasia, neglect, severe cognitive impairment, substantial sensory loss, or difficulty following instructions. Their

findings mainly concern selected patients with mild to moderate impairments who can manage structured training [20-21, 29, 37].

Stroke phase also affects how gains are interpreted. In the acute and early subacute phases, spontaneous recovery and usual rehabilitation occur alongside the tested intervention. A single-group comparison or passive control cannot readily isolate the intervention's added effect. Chronic-phase studies are less affected by spontaneous recovery, but often select patients with stable function who can sustain participation in training [20, 43, 55-56]. The evidence does not establish one optimal treatment window for every intervention or outcome. Timing needs to be considered in relation to the target, the training load a patient can tolerate, and the outcome sought [4, 57].

Many studies are pilot or feasibility trials, intended to assess recruitment, adherence, safety, and whether procedures can be delivered, and to inform later confirmatory trials. They cannot carry the same weight as definitive effectiveness studies [22, 42, 58-59]. Active, dose-matched controls help separate the intervention's core components from repeated practice, therapist contact, and expectations. In some combined programs, however, total training time, therapist attention, or concurrent usual rehabilitation remains unequal between groups [20, 35, 60].

Incomplete reporting makes interventions difficult to interpret or reproduce [61]. An assessment of 27 randomized trials found that none fully reported all 12 items of the Template for Intervention Description and Replication (TIDieR) checklist. Only 22% adequately described who delivered treatment, and materials, procedures, and individualized adjustments were often missing [61]. Outcome selection is another problem. MoCA, MMSE, the Barthel Index (BI), modified Barthel Index (MBI), and Functional Independence Measure (FIM) are common, but performance-based IADL, untrained home or community tasks, patient goals, and participation are less often measured [13, 25]. Follow-up is generally limited, and reports often omit home practice, booster treatment, caregiver support, or other rehabilitation received during follow-up. Without that information, the source and stability of a lasting effect remain difficult to judge [13, 61].

5.5 Implications for Clinical Practice

Treatment selection should start with what prevents the patient from completing an important daily activity. Limited cognitive or motor abilities may call for targeted restorative training, physical activity, or an adjunct to training. Difficulties with awareness, strategy generation, or self-monitoring may call for metacognitive or compensatory methods. Problems with a particular daily activity can be addressed through practice that closely reproduces that task [8, 13, 22]. This is a way to organize clinical reasoning, not a validated treatment algorithm. Bottom-up and top-down work can proceed together, alternate, or be recombined as the patient's needs change [23, 53, 62].

The delivery platform should not be mistaken for the treatment mechanism. A computer, virtual environment, or dual-task format may provide repeated ability training, strategy practice, or activities performed in context. Brain stimulation is better used as an adjunct to active training, while music can provide cognitive stimulation and participation support with little equipment [21, 37, 46, 51]. Treatment targets and patient goals should drive technology choice, rather than the novelty of a device [23, 53]. Caregiver roles should also be explicit: support strategy use, reduce unnecessary prompts, and help extend practice from the therapy room into home and community activities [8, 22, 54].

Each outcome answers a different clinical question. Cognitive tests show whether the assessed ability has changed. Performance-based IADL assessments show whether a complex task can be completed more safely or with fewer prompts. Participation measures address return to family, work, and community roles; quality of life and caregiver burden capture how patients and families experience the change [3, 6, 12, 33]. These measures should be used together, not interchangeably. Assessment must also distinguish benefit at treatment completion from benefit sustained through continuing treatment and from maintenance after treatment stops [12, 22].

Table 2 links these clinical questions to outcome measures and the conclusions each can support.

Table 2 Outcome Selection for Functional Gains, Transfer, and Maintenance

Assessment target	What to measure	What the result can support	What it cannot establish alone
Cognitive change	Global and domain-specific tests aligned with the intervention target [1, 4, 7].	Change in the assessed cognitive domain.	Daily-life independence, social participation, or cognitive mediation of functional change.
Performance on trained daily tasks	Completion quality, errors, safety, prompting, and assistance during patient-selected activities [8, 22, 33].	Functional gain in the practiced activity.	Transfer to a task or setting that was not trained.
Untrained tasks and settings	Performance-based IADL and observation of untrained home or community tasks; record overlap with training [13, 17, 19, 33].	Transfer when the assessed task or context was not directly practiced.	Maintenance after treatment or transfer to all daily activities.
Social participation	Involvement in family, work, community, and social roles relevant to the patient [3, 5, 12].	Change in the participation domain actually measured.	Equivalent change in cognitive test scores or independence in all activities.
Patient and caregiver experience	Quality of life, perceived occupational performance, and caregiver burden [6, 32, 51].	The perceived meaning and burden of change for patients and caregivers.	Objective task performance or a specific cognitive mechanism.

Assessment target	What to measure	What the result can support	What it cannot establish alone
Maintenance after intervention	Repeat the same outcomes after training ends; report timing, home practice, aids, booster sessions, and caregiver support [12, 22-23, 54].	Persistence over the stated interval under the documented support conditions.	Long-term durability from a brief follow-up or effects after withdrawal of all support.

Note: Outcome domains should be assessed in parallel and should not substitute for one another. This table operationalizes the review framework; it does not specify a validated core outcome set or a fixed follow-up schedule. Abbreviations: IADL, instrumental activities of daily living.

5.6 Research Gaps and Future Directions

Future studies need consistent descriptions of participants, stroke phase, and cognitive phenotype. Clear phase definitions and prespecified collection of pre-stroke cognition, lesion characteristics, stroke severity, affected cognitive domains, and motor and language impairments would reduce the risk of combining patients with different recovery processes and treatment needs [4, 55, 57]. A global screening score alone is not enough. Domain-specific tests should match the treatment target, and cognitive phenotype should be considered in stratification because it may affect other aspects of rehabilitation [1, 4, 7]. Recruitment should also better represent older patients, those with severe cognitive impairment, aphasia, or multiple coexisting conditions, and people with limited digital access. Evidence drawn mainly from those who find training easiest leaves important clinical groups underrepresented.

Trials should test functional transfer directly. At a minimum, the same study should assess global and domain-specific cognition, observed performance on untrained IADL tasks, patient-prioritized goals, participation, quality of life, and caregiver burden. Short-, medium-, and long-term follow-up after treatment should be prespecified. Functional assessment should record task quality, error types, safety, prompting and assistance needs, and generalization across settings, rather than only total scale scores [22, 33]. Measuring cognitive change, strategy use, task performance, and participation together, with prespecified mediator or process data to establish their time sequence, would provide stronger evidence on whether and how cognitive improvement contributes to everyday functioning [23, 53].

6 CONCLUSION

Nonpharmacological rehabilitation for PSCI has been studied more thoroughly for trained-task gains and near cognitive transfer than for complex IADL, social participation, or long-term maintenance after treatment. Consistent evidence for these latter outcomes is still lacking [12-13, 25]. Clinical decisions should focus less on ranking individual techniques and more on identifying what limits a patient's daily functioning, then combining relevant ability training, strategies, task practice, and support at home and in the community. Trials need clear, reproducible intervention descriptions and long-term assessments of real-life performance at several functional levels to determine whether cognitive gains translate into daily-life benefit [4, 23, 53, 63].

COMPETING INTERESTS

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