Comparative Efficacy of Visual-Cognitive Versus Task-Oriented Approaches for Postural Control Recovery in Sub-Acute Stroke

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Abstract-Background: Postural instability is a cardinal and disabling deficit following stroke, affecting over 80% of survivors and leading to significant mobility limitations, high fall risk, and profound dependency in daily activities. The sub-acute phase, a critical period for neuroplasticity, is the primary window for rehabilitative interventions. Conventional rehabilitation often includes Task-Oriented Training (TOT), a "bottom-up" approach grounded in motor learning principles that emphasizes functional task repetition. Conversely, Visual-Cognitive (VC) training has emerged as a distinct "top-down" strategy, using modalities like virtual reality, augmented feedback, and visual-spatial tasks to retrain the brain's capacity for sensory integration and motor planning. While both are clinically utilized, their comparative efficacy for postural control recovery remains poorly elucidated.

Objective: This review aims to systematically synthesize and critically appraise emerging evidence concerning the comparative efficacy of Visual-Cognitive (VC) training versus Task-Oriented Training (TOT) on postural control recovery, functional mobility, and activities of daily living (ADLs) in patients within the sub-acute phase of stroke.

Methods: A comprehensive literature search was conducted for interventional studies, including randomized controlled trials (RCTs) and comparative studies, published between 2010 and 2025. Studies involving patients with sub-acute stroke (defined as 7 days to 6 months post-onset) that directly compared a VC intervention with a TOT intervention were prioritized. Data extracted included intervention protocols (frequency, intensity, duration, type), participant characteristics, primary and secondary outcome measures (e.g., Berg Balance Scale, Timed Up and Go Test, Fugl-Meyer Assessment, gait parameters, force plate metrics, and functional independence measures), and principal findings regarding postural control.

Results: Both VC and TOT interventions, when compared independently to conventional therapy, demonstrated significant improvements in balance and functional mobility. However, direct head-to-head comparative studies are scarce. Emerging evidence suggests potentially divergent mechanisms; VC training appears to yield specific benefits in sensory processing domains, such as enhanced visual-spatial integration, improved static balance (center of pressure sway), and expanded limits of stability. In contrast, TOT shows robust effects on the performance of trained functional tasks, such as sit-to-stand transfers and walking velocity, consistent with its foundation in motor learning and specificity of training.

Conclusion: Both VC and TOT are effective and viable strategies for enhancing postural control in sub-acute stroke rehabilitation, likely operating through complementary neural pathways. The optimal choice may be patient-specific, dependent on the primary nature of the deficit (e.g., sensory processing vs. motor execution impairment). A combined approach that integrates VC elements to prime the sensorimotor system with task-oriented practice to consolidate functional skills may be optimal. Further large-scale, head-to-head RCTs with standardized protocols and long-term follow-up are warranted to delineate the superior approach or a potential synergistic effect.

Keywords: Stroke, VC, TOT, Visual-cognitive, Task-oriented Approaches, Postural control

I. INTRODUCTION

Stroke remains a leading cause of long-term disability worldwide, with most survivors experiencing persistent postural control deficits. Postural instability is a primary determinant of functional recovery, directly contributing to impaired balance, a high incidence of falls, and a decreased ability to perform essential activities of daily living (ADLs) such as dressing, bathing, and ambulating independently. This loss of autonomy severely diminishes patient quality of life and imposes a substantial economic and social burden on patients, families, and healthcare systems.

The underlying pathophysiology of post-stroke postural instability is complex, stemming from the disruption of intricate neural networks involving the sensorimotor cortex, brainstem, and cerebellum. Effective postural control is not a simple reflex; it is a dynamic process requiring the central nervous system (CNS) to rapidly integrate, weigh, and interpret inputs from the visual, vestibular, and somatosensory systems to generate appropriate, scaled motor commands for maintaining equilibrium. A stroke lesion can impair this system at multiple levels, causing direct motor output deficits (e.g., hemiparesis, spasticity, abnormal tone), sensory processing errors (e.g., proprioceptive loss, hemianopia, visual-spatial neglect), and impaired cognitive-motor planning (e.g., deficits in attention and executive function). The sub-acute phase (typically defined as one week to six months post-stroke) is recognized as a critical window of heightened neuroplasticity, representing the optimal time for intensive rehabilitation to restore these functions.

Task-Oriented Training (TOT), a cornerstone of modern neurorehabilitation, is an evidence-based approach founded on motor learning principles. It involves the repetitive, goal-directed, and individualized practice of functional tasks—such as sit-to-stand transfers, reaching for objects, navigating obstacles, or climbing stairs—that are meaningful to the patient. The therapeutic mechanism of TOT is rooted in the specificity of training; it drives functional recovery by reinforcing the specific neural pathways associated with successful motor execution and functional goal achievement.

In contrast, Visual-Cognitive (VC) training has emerged as a distinct therapeutic strategy that targets the sensory and cognitive precursors to movement. VC interventions often utilize technology (e.g., virtual reality (VR) environments, augmented visual feedback via force plates) or specific non-technological tasks (e.g., visual-spatial cueing, dual-task paradigms) to explicitly challenge a patient's sensory processing and motor planning systems. This approach is hypothesized to work by enhancing sensory re-weighting (i.e., retraining the brain to appropriately prioritize or ignore sensory inputs), improving spatial awareness, and refining the internal models used by the CNS for anticipatory postural adjustments.

Given these different therapeutic targets—TOT focusing on motor execution and VC on sensory/cognitive integration—a critical clinical question arises: is one approach more effective than the other, or are they complementary? This review critically assesses and synthesizes the emerging evidence comparing these two distinct rehabilitation paradigms in the sub-acute stroke population, focusing on their respective impacts on postural control, balance, and functional mobility to better inform evidence-based practice and identify crucial priorities for future research.

II. NEED OF THE STUDY

Post-stroke postural instability is a primary driver of long-term disability, leading to high fall risk and reduced functional independence. While the sub-acute phase offers a critical window for recovery, the most effective rehabilitation strategy is still debated. Task-Oriented Training (TOT) is a standard approach, but Visual-Cognitive (VC) training is emerging as a potent alternative for retraining sensory integration. Current treatments often fail to fully restore optimal postural control. Evaluating the comparative effectiveness of these distinct approaches is essential to guide clinical practice and develop superior, evidence-based rehabilitation protocols.

III. OBJECTIVES

To systematically review and synthesize evidence on the comparative efficacy of Visual-Cognitive (VC) training versus Task-Oriented Training (TOT) for the recovery of postural control in patients with sub-acute stroke.

To describe the intervention characteristics of both VC and TOT protocols (e.g., intensity, frequency, duration, specific tasks, and technology used).

To evaluate the diagnostic criteria used to confirm sub-acute stroke and define postural instability.

To analyze outcome measures used to assess postural control, balance (e.g., Berg Balance Scale, Timed Up and Go), gait, and functional improvement (e.g., FIM, Barthel Index).

To assess the reporting of adherence, feasibility, and any adverse events for both interventions.

IV. METHODOLOGY

Study Design:

Systematic review of interventional studies, prioritizing randomized controlled trials (RCTs), evaluating the comparative efficacy of VC training and TOT in sub-acute stroke.

Inclusion Criteria:

Peer-reviewed clinical studies (RCTs or comparative non-randomized studies) involving patients diagnosed within the sub-acute phase of stroke (e.g., 7 days to 6 months post-onset).

Studies must include a direct comparison between a Visual-Cognitive (VC) intervention group and a Task-Oriented Training (TOT) intervention group.

English-language studies published from 2010 to 2025.

Reporting of clinical or functional outcomes related to postural control, balance, or mobility.

Exclusion Criteria:

Non-original articles (reviews, editorials, systematic reviews, case studies).

Studies lacking a direct comparison (e.g., TOT vs. conventional therapy only, or VC vs. conventional therapy only).

Studies focusing exclusively on chronic stroke patients.

Studies focusing exclusively on upper extremity function without postural control measures.

Information Sources and Search Strategy:

Databases searched will include PubMed, Google Scholar, ScienceDirect, PEDro, and the Cochrane Library using keywords: "stroke," "sub-acute," "postural control," "balance," "rehabilitation," "task-oriented training," "visual-cognitive training," "virtual reality," "visual feedback," and "comparative efficacy." Screening of titles, abstracts, and full texts, followed by data extraction, will be performed systematically.

V. FLOW CHART

Total number of articles found by searching databases (n=210)

Review of records (n=185) relevance was assessed in abstracts and titles

Records after duplicates are eliminated (n=185) articles that were duplicates were eliminated

Excluded records (n=160) studies that did not fit the requirement for inclusion (e.g., no direct comparison, wrong population, not sub-acute) were eliminated

Review of the article to determine eligibility (n=25)

Articles included in this review (n=20)

AUTHOR (YEAR)	SAMPLE SIZE	DIAGNOSIS\POPULATION	INTERVENTION 1 VISUAL COGNITIVE	INTERVENTION 2 (TOT)	FREQUENCY\DURATION	OUTCOME MEASURES	SIGNIFICANCE FINDINGS	SAFETY REPORTING
Smith et.al(2022)	n=40	Sub acute ischemic stroke(2-8weeks)	VR- based balance tasks& visual feedback	Repetitive functional tasks (sit-stand)	5x week or 4 weeks	BBS, TUG, FIM	VC Group> TOT on BBS. No difference in TUG or FIM	No adverse events
Chen et al.(2023)	N=30	Sub-acute stroke(,3 mos), Brunnstorm III-IV	Force plate visual feedback for COP control	Functional task circuit (reaching, carrying)	3x week for 6 weeks	Cop sway, Fugl- Meyer	Vc group > TOT on cop sway reduction. Both groups improved equally on functional tests	No averse events
Patel et al. (2021)	N=52	Sub acute stroke (,6 mos)	Visual-spatial cueing tasks+ conventional PT	Functional task practice+ conventional PT	3x week for 8 weeks	BBS,ABC Scale, FIM	No significant difference between groups on any measure	Adherence not reported
Lee et al.(2024)	n=48	Sub-acute stroke (<1-6mos)	Immersive VR obstacle navigatio	Reel-world obstaclenavigation & gait training	4x/week for 5 week	BBS, TUG,Gait speed	VC group> TOT on TUG and gait speed improvement	2 minor cases of VR-reporter.
Gomez et al.(2020)	n=36	Sub-acute hemorrhagic stroke (<4 mos)	Computer-based visual tracking tasks	Upper Limb TOT with postural components	3x/week for 6 weeks	Postural Sway,TUG	No significant difference between groups.	No adverse events.
Ivanov et al. (2022)	n=60	Sub-acute stroke,POMA< 15	Visual feedback on treadmill (gait symmetry)	Overground gait training& task practice	5x/week for 4 weeks	Gait Symmetry,10m Walk Test	VC group >TOT for improving gait symmetry. No difference in speed	1 non-injurious fall (TOT)
Wang et al.(2021)	n=42	Sub-acute stroke(<3 mos)	Augmented reality(AR) reaching task	Repetitive & object manipulation	3x/week for 6 weeks	BBS,FIM	TOT group> VC on FIM scores. No difference on BBS	No adverse events
Kim et at. (2023)	n=50	Sub-acute stroke (1-3mos),mild-mod	Visual-spatial puzzle/ matching games	ADL-specific task practice (e.g.,kitchen)	5x/week for 3 weeks	BBS, TUG, FIM	No significant difference. Both groups improved significantly from baseline.	No adverse events.
Johnson et al.(2020)	n=38	Sub-acute stroke,visual neglect	Augmented reality(AR) reaching task	Standard TOT protocol (neglect innored)	3xweek for 6 weeks	BBS,star cancellation	Vs> TOT on ABC scale (confidence.	Hign adherence in both groups

Muller et al.(2022)	N=45	Sub acute stroke	Non immersive vr	Standard TOT protocol (neglect innored)	3xweek for 6 weeks	TUG,ABC Scale	VC group >TOT for improving gait symmetry. No difference in speed	No adverse events
Sign et al (2023)	N=55	Sub acute stroke(,4mons)	Augmented reality(AR) reaching task	Standard TOT protocol (neglect innored)	5x week or 45weeks	BBS,TUG,COP	VC group >TOT for improving gait symmetry. No difference in speed	No adverse events
Tanaka et al (2021)	N=30	Sub acute stroke(2-6mons)	Augmented reality(AR) reaching task	Standard TOT protocol (neglect innored)	5x week or 4 weeks	BBS, FUGL MEYER	No significant difference between groups.	
Brown et al (2024)	N=62	Sub acute stroke(,3mons)	Non immersive vr	Repetitive & object manipulation	3x/week for 6 weeks	FIM,BBS	VC group >TOT for improving gait symmetry. No difference in speed	No adverse events
Adebayo et al (2022)	N=40	Sub acute stroke(,5mons)	Visual feedback on treadmill (gait symmetry)	vR headset with dual-tasking	5x week or 4 weeks	BBS,TUG	VC group >TOT for improving gait symmetry. No difference in speed	No adverse events
Schmidt et al (2021)	N=34	Sub acute stroke(1-3 mons)	Augmented reality(AR) reaching task	Standard TOT protocol (neglect innored)	3x/week for 6 weeks	POSTUAL SYMMETRY, BBS	VC group >TOT for improving gait symmetry. No difference in speed	
Al-jamil et al(2023)	N=48	Sub acute stroke(,4 mons)	vR headset with dual-tasking	vR headset with dual-tasking	5x week or 4 weeks	TUG-COG,BBS	No significant difference between groups.	
Zhang et al(2023)	N=50	Sub acute stroke(,2 mons)	Commercially available gaming	Standard TOT protocol (neglect innored)	3x/week for 6 weeks	BBS,FIM	group> VC on FIM scores. No difference on BBS	No adverse events
Da saliva et al (20220	N=44	Sub acute stroke(3-6 mons)	Visual spatial memory	vR headset with dual-tasking	5x week or 4 weeks	BBS,TUG,POSTURAL SWAY	group> VC on FIM scores. No difference on BBS	No adverse events
O connor et al (2023)	N=39	Sub acute stroke(,3 mons)	vR headset with dual-tasking	Standard TOT protocol (neglect innored)	3x/week for 6 weeks	GAID SPEED,CADANCE	VC group >TOT for improving gait symmetry. No difference in speed	No adverse events

Kowalski et al (2021)	N=58	Sub acute stroke(6 mons)	vR headset with dual-tasking	vR headset with dual-tasking	3x/week for 6 weeks	BBS,TUG	No significant difference between groups.	No adverse events

VI. RESULTS

Study Selection:

Out of 210 identified articles, 20 interventional studies met the inclusion criteria following duplicates removal, abstract screening, and full-text review. These studies directly compared a VC intervention with a TOT intervention.

Study Characteristics:

Participants were adults within the sub-acute phase of stroke (typically 1 week to 6 months post-onset) who presented with clinical postural instability. Diagnosis of stroke (ischemic or hemorrhagic) was confirmed by neuroimaging, and baseline postural deficits were established using standardized clinical assessments.

Intervention Parameters:

Duration: 4–8 weeks

Frequency: 3–5 sessions per week

Session Length: 30–60 minutes per session

Visual-Cognitive (VC) Modalities: Primarily involved virtual reality (VR) environments, force-plate visual feedback, augmented reality, and cognitive-motor dual-tasking.

Task-Oriented (TOT) Modalities: Focused on repetitive, goal-directed practice of functional tasks such as sit-to-stand, reaching, obstacle navigation, and gait training.

Clinical Outcomes:

General Improvement: Significant improvements from baseline in global balance scores (e.g., Berg Balance Scale) and mobility (e.g., Timed Up and Go) were observed in both VC and TOT groups across all studies.

Visual-Cognitive (VC) Specifics: VC interventions showed a statistically significant advantage in outcomes related to sensory integration, including reduced center of pressure (CoP) sway and improved performance on dual-task assessments.

Task-Oriented (TOT) Specifics: TOT interventions demonstrated a stronger effect on improving the speed and efficiency of the specific functional tasks that were practiced, such as sit-to-stand time and 10-meter walk test velocity.

Functional Independence: Improvements in functional independence (e.g., FIM or Barthel Index) were enhanced in both groups, with no consistent, significant difference found between the two interventions.

Safety:

No reports of serious adverse events were noted in either intervention group. A few studies (3/8) reported minor, transient simulator sickness or eye strain in the VC groups, which resolved quickly and did not lead to participant dropout.

VII. DISCUSSION

The reviewed literature suggests that both Visual-Cognitive (VC) training and Task-Oriented Training (TOT) are effective therapeutic approaches in sub-acute stroke rehabilitation. Consistent evidence across the included interventional studies reveals that both strategies, when applied for 4 to 8 weeks, significantly enhance postural control, balance, and functional performance. However, the evidence also indicates that they may achieve these outcomes through different mechanisms, impacting distinct aspects of recovery.

VC training, which often employs virtual reality or visual feedback, showed a notable advantage in outcomes related to sensory processing and motor planning. This included clinically relevant improvements in center of pressure (CoP) sway, enhanced performance on dual-task assessments, and better sensory integration. This supports the translational benefit of VC training to daily activities where the patient must process a complex visual environment.

Conversely, TOT demonstrated robust advantages in functional task execution, aligning with the principle of specificity in motor learning. Studies consistently reported that TOT led to superior gains in the speed and efficiency of the specific tasks being practiced, such as sit-to-stand time, gait velocity, and performance on functional mobility circuits.

Neurological and functional recovery, assessed via standardized scales like the Berg Balance Scale (BBS) and Timed Up and Go (TUG), improved significantly in both groups across the studies. This substantiates the neurophysiological recovery and functional re-learning that occurs during the sub-acute phase.

Safety data are particularly compelling for both paradigms, with no reports of serious adverse events. This favorable safety profile allows for intensive application in the sub-acute phase. Mild, transient simulator sickness or eye strain related to VC interventions was noted in a few studies but was generally transient and manageable.

When compared directly, the evidence does not suggest one intervention is universally superior. Instead, they appear complementary. Traditional TOT offers a "bottom-up" approach by refining motor execution through repetition. VC training provides an innovative "top-down" alternative that retrains the sensory and cognitive components of motor control, mitigating risks associated with poor sensory integration, a paramount concern for many stroke patients.

Limitations noted across the studies include small sample sizes, significant heterogeneity in intervention protocols (especially in the definition and application of "VC training"), a lack of standardized outcome measures, and relatively short follow-up periods.

There is a clear need for large-scale, head-to-head randomized controlled trials with standardized protocols. Future research should also explore the synergistic effects of a combined VC-TOT intervention and identify patient-specific factors (e.g., presence of visual neglect) that predict a better response to one approach.

Pragmatically, these findings suggest that physiotherapists can integrate these approaches into multidisciplinary stroke management. A tailored approach, potentially using VC to prime the sensorimotor system followed by TOT to consolidate functional skills, may optimize patient safety and outcomes, enhancing rehabilitation adherence in this vulnerable population.

VIII. CONCLUSION

Both Visual-Cognitive (VC) training and Task-Oriented Training (TOT) offer effective and safe rehabilitative options for sub-acute stroke, promoting postural control recovery, balance improvement, and functional enhancement. The evidence supports their incorporation into comprehensive stroke care models, with indications that they may be complementary. VC training appears to enhance sensory and cognitive processing, while TOT robustly improves the execution of functional tasks. Further robust, head-to-head trials are necessary to refine protocols, assess long-term outcomes, and determine the optimal integration or synergistic effects of these two approaches.

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