

Immersive Virtual Reality-Based Dual-Task Training in Pediatric Neurorehabilitation: A Scoping Review

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INTRODUCTION

Background

Pediatric neurological disorders can produce persistent limitations in motor performance, balance, gait, coordination, attention, executive functioning, visuospatial processing, and participation. Cerebral palsy (CP) represents an important population in pediatric neurorehabilitation because children with CP may experience both motor and cognitive limitations that affect functional activities. Difficulties in balance, selective motor control, gait, and coordination may be accompanied by impairments in attention and other cognitive processes.

Functional activities in daily life rarely require children to perform motor tasks in isolation. Walking while talking, navigating an environment while searching for an object, walking while remembering instructions, or maintaining balance while responding to environmental information are examples of **dual-task activities**. Consequently, the ability to divide or coordinate attentional resources between cognitive and motor tasks may have important implications for functional independence.

Research examining dual-task performance in children with CP has demonstrated that the addition of a concurrent task can adversely influence gait performance. A systematic review and meta-analysis reported slower walking speed during dual-task conditions compared with single-task walking in children with CP.

A 2025 scoping review specifically examining dual-task training in children with CP identified six studies involving 117 children. The interventions included both motor-motor and motor-cognitive paradigms, with training durations ranging from 480 to 1,800 minutes. All included studies reported improvement in primary motor-task performance, although substantial heterogeneity existed in intervention characteristics and outcome measures. More recent evidence continues to demonstrate interest in pediatric dual-task training. A 2026 systematic review and meta-analysis identified eight randomized controlled trials involving 180 children with CP and reported low- or very-low-certainty evidence across several outcomes, highlighting the need for better standardized protocols and outcome measurement.

Virtual Reality in Pediatric Neurorehabilitation

Virtual reality (VR) provides computer-generated environments in which users can interact with visual, auditory, and sometimes haptic stimuli. In rehabilitation, VR can provide repetitive, task-oriented practice with immediate feedback and adjustable task difficulty.

Previous systematic reviews have reported beneficial effects of VR interventions on balance and walking in children with CP. One review included 26 studies and reported favorable effects of VR for both balance and walking.

Another systematic review and meta-analysis involving 16 studies and 513 children with CP reported improvements in balance and gross motor function following VR interventions. Evidence specifically concerning **immersive VR** is more limited. A systematic review of immersive VR interventions in pediatric

CP identified 15 studies and reported considerable heterogeneity in outcomes. The authors described immersive VR as potentially useful as an adjunct to conventional rehabilitation, while emphasizing the limited and heterogeneous evidence base.

Importantly, VR may also influence cognitive domains. A randomized controlled study involving 90 children with hemiplegic CP reported greater improvement in several cognitive-function measures in children receiving VR-based rehabilitation combined with traditional occupational therapy compared with traditional therapy alone.

An immersive VR study involving 35 young people with CP investigated navigation and visuospatial abilities and reported improvements in visual-spatial performance following IVR-based training, particularly when navigation strategies were specifically trained.

These findings provide a rationale for investigating whether IVR can be deliberately designed to combine **cognitive processing with functional movement** rather than simply using VR as an alternative environment for conventional exercise.

Rationale for Combining IVR and Dual-Task Training

The combination of IVR and dual-task training is theoretically attractive for pediatric neurorehabilitation for several reasons.

R Can Provide

- controlled visual environments;
- adjustable cognitive complexity;
- real-time feedback;
- repetitive task practice;
- graded environmental challenges;
- obstacle negotiation;
- navigation activities;
- target identification;
- working-memory tasks;
- divided-attention tasks;
- visuospatial challenges;
- motivating game-based activities.

Dual-Task Training Can Provide

- simultaneous cognitive-motor practice;
- cognitive-motor interference training;
- attentional-demand manipulation;

- task prioritization;
- adaptation to environmental distractions;
- greater ecological relevance.

Thus, IVR may provide an environment in which dual-task demands can be systematically manipulated.

For example:

Walking → virtual environment → obstacle avoidance → counting targets → remembering instructions → changing direction

could represent a progressive cognitive-motor training paradigm.

Research Gap

The literature currently appears to consist of several partially overlapping evidence streams:

Evidence area	Current evidence
VR in pediatric CP	Relatively substantial
Immersive VR in pediatric CP	Emerging
VR and cognitive function	Emerging
Dual-task assessment in pediatric CP	Increasing
Dual-task training in pediatric CP	Emerging
IVR + dual-task training	Limited
IVR + DTT + cognitive outcomes	Very limited
IVR + DTT + functional mobility	Very limited
IVR + DTT across multiple pediatric neurological disorders	Major evidence gap

Importantly, a 2025 scoping review has already mapped **dual-task training and mobility outcomes in children with CP**, while a separate body of reviews has examined VR interventions in CP.

Therefore, your proposed review should make its novelty explicit:

Rather than reviewing VR alone or dual-task training alone, this review will map the intersection of immersive VR, dual-task training, cognitive function, and functional mobility across ambulatory pediatric neurological populations.

That distinction is important for publication.

Review Objective

Primary objective

To systematically map the available evidence regarding the use and effects of immersive virtual reality-

based dual-task training on cognitive function and functional mobility in ambulatory children with pediatric neurological disorders.

Secondary objectives

1. To identify the neurological populations studied.
2. To describe the characteristics of IVR systems used.
3. To classify the cognitive and motor components of dual-task interventions.
4. To identify intervention dosage and progression strategies.
5. To identify cognitive outcome measures.
6. To identify functional mobility outcome measures.
7. To summarize reported effects on cognitive function.
8. To summarize reported effects on functional mobility.
9. To identify adverse events, feasibility, adherence, and acceptability.
10. To identify methodological and clinical gaps for future research.

Review Question

Main question

What is the current evidence regarding immersive virtual reality-based dual-task training for improving cognitive function and functional mobility in ambulatory children with pediatric neurological disorders?

Subquestions

1. What pediatric neurological populations have been studied?
2. What types of immersive VR systems have been used?
3. What cognitive tasks are incorporated into dual-task training?
4. What motor tasks are incorporated?
5. What cognitive outcomes have been evaluated?
6. What functional mobility outcomes have been evaluated?
7. What intervention dosage and duration have been used?
8. What effects have been reported?
9. What adverse events and feasibility outcomes have been reported?
10. What evidence gaps remain?

PCC Framework

JBIR recommends the **Population–Concept–Context (PCC)** framework for developing scoping-review questions and inclusion criteria.

PCC	Proposed definition
Population	Ambulatory children/adolescents with neurological disorders
Concept	Immersive VR-based dual-task training
Context	Pediatric neurorehabilitation/physiotherapy/occupational therapy/community or home-based rehabilitation

Population

Children and adolescents approximately **5–18 years** with neurological disorders, including:

- cerebral palsy;
- acquired brain injury;
- traumatic brain injury;
- developmental neurological disorders;
- spina bifida;
- neuromuscular/neurological disorders where ambulation is preserved;
- other pediatric neurological conditions.

Concept

Training must involve:

VR + motor task + simultaneous cognitive task

Examples:

- walking + counting;
- walking + memory task;
- balance + target identification;
- obstacle negotiation + decision making;
- gait + visuospatial navigation;
- walking + response inhibition;
- mobility + working memory.

Context

- physiotherapy;
- pediatric neurorehabilitation;
- rehabilitation centers;
- hospitals;
- outpatient clinics;
- community settings;
- home-based rehabilitation.

Operational Definition of Immersive VR

This is particularly important for your review.

For this review:

Immersive virtual reality will refer to technology that provides a computer-generated three-dimensional environment designed to create a strong sense of presence through head-mounted or comparable immersive display systems, allowing active interaction with the virtual environment.

Studies using ordinary television/screen-based exergaming should be categorized as **non-immersive VR** and excluded from the primary analysis.

Semi-immersive systems can either:

1. be excluded, or
2. be included and analyzed as a separate subgroup.

I recommend the second approach because it will prevent potentially relevant evidence from being unnecessarily discarded.

Inclusion Criteria

Studies will be eligible if they:

- involve children/adolescents with a neurological disorder;
- include ambulatory participants;
- use immersive or substantially immersive VR;
- incorporate a motor and cognitive task simultaneously;
- evaluate training rather than only assessment;
- report cognitive, motor, functional mobility, or related outcomes;
- include experimental, quasi-experimental, observational, feasibility, or pilot designs;
- are peer-reviewed;

- are available in English.

Study designs

Include:

- randomized controlled trials;
- controlled clinical trials;
- quasi-experimental studies;
- single-group pre-post studies;
- feasibility studies;
- pilot studies;
- observational intervention studies.

Because this is a scoping review, restricting the review to RCTs would unnecessarily narrow the evidence map. JBI methodology supports consideration of different evidence types in scoping reviews.

Exclusion Criteria

Exclude studies involving:

- adults only;
- non-neurological pediatric populations;
- non-ambulatory participants only;
- non-immersive VR only;
- VR used solely for entertainment;
- VR used solely for upper-limb rehabilitation without a mobility component;
- VR assessment without training;
- single-task training without simultaneous cognitive-motor demands;
- surgical or pharmacological interventions without relevant VR training;
- conference abstracts without sufficient information;
- editorials and opinion pieces.

Information Sources

I recommend searching:

1. **PubMed/MEDLINE**
2. **Scopus**

3. **Web of Science**
4. **Embase**
5. **CINAHL**
6. **PEDro**
7. **Cochrane CENTRAL**
8. **PsycINFO**

Additional searching:

- Google Scholar;
- reference lists of included studies;
- citation tracking;
- clinical trial registries where appropriate.

JBIR's updated search methodology emphasizes appropriate database selection, structured searching, collaboration with information specialists, and transparent documentation of the search process.

Proposed PubMed Search Strategy

A three-concept search is preferable.

Concept 1 – Pediatric neurological population

(child* OR pediatric* OR paediatric* OR adolescent* OR youth*)

AND

(neurolog* OR "cerebral palsy" OR "brain injury" OR

"traumatic brain injury" OR "spina bifida" OR

"developmental disorder*" OR "neuromuscular disorder*")

Concept 2 – Immersive VR

("virtual reality" OR "immersive virtual reality" OR

"immersive VR" OR "head mounted display*" OR

"head-mounted display*" OR HMD OR

"virtual environment*" OR "3D virtual environment*")

Concept 3 – Dual task

("dual task*" OR "dual-task*" OR

"dual task training" OR "cognitive motor" OR

"cognitive-motor" OR "motor-cognitive" OR

"cognitive motor training" OR

"cognitive-motor interference")

Concept 4 – Outcomes

("cognitive function" OR cognition OR

"executive function" OR attention OR memory OR

"working memory" OR "functional mobility" OR

gait OR walking OR balance OR "Timed Up and Go" OR TUG)

Combined strategy

(child* OR pediatric* OR paediatric* OR adolescent* OR youth*)

AND

(neurolog* OR "cerebral palsy" OR "brain injury" OR

"traumatic brain injury" OR "spina bifida" OR

"developmental disorder*" OR "neuromuscular disorder*")

AND

("virtual reality" OR "immersive virtual reality" OR

"immersive VR" OR "head mounted display*" OR

"head-mounted display*" OR HMD OR "virtual environment*")

AND

("dual task*" OR "dual-task*" OR

"dual task training" OR "cognitive motor" OR

"cognitive-motor" OR "motor-cognitive")

I would **not make the outcome terms mandatory in the primary search**, because doing so could miss studies that measure cognition or mobility using unexpected terminology.

Study Selection

The selection process should follow:

Identification → Deduplication → Title/abstract screening → Full-text screening → Included studies

Two independent reviewers should ideally perform:

- title/abstract screening;

- full-text screening;
- data extraction.

Disagreements should be resolved through discussion or a third reviewer.

The final review should report a **PRISMA-ScR flow diagram**. PRISMA-ScR provides the reporting framework specifically developed for scoping reviews.

Data Extraction Framework

Create a standardized extraction sheet with the following fields:

Domain	Variables
Bibliographic	Author, year, country
Study design	RCT, quasi-experimental, pilot etc.
Sample	Sample size, age, sex
Diagnosis	CP, ABI, TBI, etc.
Ambulation	GMFCS/functional level
IVR	Device/system
Immersion	Immersive/semi-immersive
VR environment	Navigation, game, obstacle course etc.
Motor task	Walking, balance, stepping etc.
Cognitive task	Memory, attention, inhibition etc.
Dual-task type	Motor-cognitive/motor-motor
Duration	Minutes/session
Frequency	Sessions/week
Intervention period	Weeks
Comparator	Conventional therapy/usual care
Cognitive outcome	Tool used
Mobility outcome	Tool used
Balance	Tool used
Gait	Tool used
Adherence	Percentage/dropout

Adverse events	Yes/no
Main findings	Author-reported findings
Limitations	Study limitations

Cognitive Outcomes to Map

Potential cognitive outcomes include:

Executive function

- inhibition;
- cognitive flexibility;
- planning;
- working memory;
- problem solving.

Attention

- selective attention;
- sustained attention;
- divided attention;
- response inhibition.

Visuospatial function

- spatial orientation;
- navigation;
- visuospatial processing;
- visual perception.

Memory

- working memory;
- short-term memory;
- spatial memory.

Potential standardized measures may include:

- BRIEF/BRIEF-2;
- Trail Making-type measures;

- Digit Span;
- computerized attention tasks;
- Dynamic Occupational Therapy Cognitive Assessment;
- visuospatial/navigation assessments.

The specific instrument should be extracted rather than prespecified as mandatory.

Functional Mobility Outcomes

Potential measures include:

Timed Up and Go

TUG

10-Meter Walk Test

10MWT

6-Minute Walk Test

6MWT

Pediatric Balance Scale

PBS

Gross Motor Function Measure

GMFM-66 / GMFM-88

particularly:

- Dimension D – standing
- Dimension E – walking, running and jumping

Pediatric Evaluation of Disability Inventory

PEDI/PEDI-CAT

Functional mobility questionnaires

Other gait and mobility outcomes:

- gait velocity;
- cadence;
- stride length;
- step length;
- double-support time;

- obstacle negotiation;
- navigation accuracy;
- dual-task cost.

Dual-Task Cost

An important outcome for your review should be **dual-task cost (DTC)**.

For example:

$$DTC = \frac{Single\ Task - Dual\ Task}{Single\ Task} \times 100$$

depending on the outcome and directionality.

For gait speed:

$$DTC = \frac{ST\ gait\ speed - DT\ gait\ speed}{ST\ gait\ speed} \times 100$$

A reduction in dual-task cost may indicate improved ability to manage simultaneous cognitive-motor demands.

This may be more informative than examining single-task gait speed alone.

Proposed Evidence Map

Your results section can organize studies into four evidence clusters:

Cluster 1

IVR → cognitive outcomes

Cluster 2

IVR → functional mobility

Cluster 3

Dual-task training → cognitive-motor performance

Cluster 4

IVR + dual-task training → cognitive + functional mobility outcomes

The fourth cluster represents the **central evidence gap** of your review.

Preliminary Findings From the Current Literature

The preliminary literature search indicates that the individual components of your research question have an expanding evidence base.

VR and mobility

VR interventions in children with CP have been associated with improvements in balance, walking and gross motor outcomes in several systematic reviews and meta-analyses.

IVR

A systematic review specifically examining immersive VR in pediatric CP identified 15 studies and reported heterogeneous motor and cognitive outcomes.

VR and cognition

A randomized trial involving 90 children with hemiplegic CP reported greater improvements in cognitive-function measures following VR-based rehabilitation compared with traditional occupational therapy alone.

IVR and visuospatial/navigation function

An IVR study involving 35 children with CP investigated navigation and spatial abilities and reported improvement following IVR training.

Dual-task performance

Children with CP demonstrate altered gait performance when cognitive or motor secondary tasks are added.

Dual-task training

The 2025 scoping review of DTT in children with CP identified six studies involving 117 children and reported improvement in primary motor-task performance across the included studies, while emphasizing heterogeneity and the need for more rigorous research.

Important current development

A 2026 systematic review/meta-analysis of DTT in children with CP included eight RCTs involving 180 participants. It found low-certainty evidence for some motor outcomes and very-low-certainty evidence for several functional mobility and walking outcomes, illustrating that the DTT evidence base is still developing.

Proposed Discussion

The evidence suggests that the three components of the proposed intervention—**virtual reality, cognitive-motor dual-tasking, and functional mobility training**—have individually or partially overlapping evidence bases in pediatric neurorehabilitation.

However, the literature should not be interpreted as demonstrating that IVR-based dual-task training itself has established efficacy. Evidence for VR alone cannot automatically be attributed to dual-task training, and evidence for conventional DTT cannot automatically be generalized to immersive VR.

This distinction is particularly important because existing studies differ considerably in:

- neurological diagnosis;
- age;
- functional level;
- type of VR;

- degree of immersion;
- cognitive task;
- motor task;
- intervention duration;
- frequency;
- outcome measures;
- comparator interventions.

The 2025 scoping review of pediatric CP DTT also identified substantial variability in intervention dosage and task paradigms.

Similarly, reviews of pediatric VR have highlighted considerable variability in outcome instruments and intervention protocols.

Therefore, the major contribution of the proposed scoping review should be **mapping the intervention architecture and evidence gaps**, rather than attempting to claim a definitive treatment effect.

Conceptual Framework

Your review can use the following conceptual pathway:

PEDIATRIC NEUROLOGICAL DISORDER



Motor impairment + Cognitive impairment



Reduced cognitive-motor integration



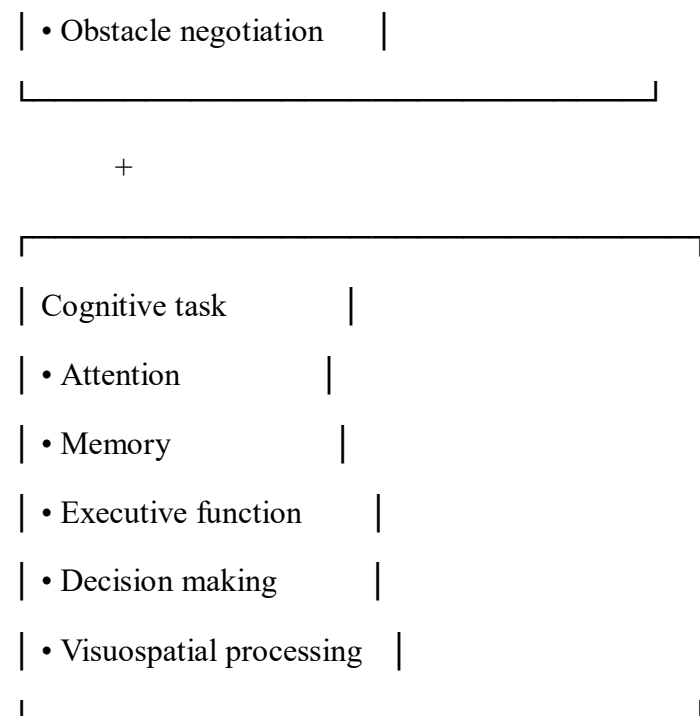
Difficulty during dual-task activities



IVR ENVIRONMENT



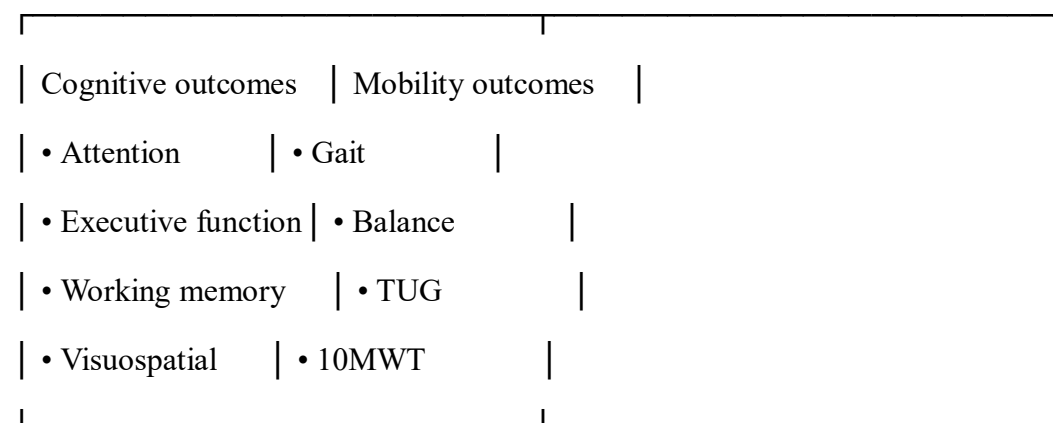
Motor task	
• Walking	
• Balance	
• Stepping	



DUAL-TASK TRAINING



Improved cognitive-motor integration



Functional participation

Research Gaps

The review should specifically examine the following gaps:

Gap 1 – Direct evidence

There appears to be limited direct research examining:

IVR + DTT → cognitive function + functional mobility

rather than evaluating VR or DTT independently.

Gap 2 – Population diversity

Most available pediatric evidence is concentrated on **cerebral palsy**, while evidence in other pediatric neurological disorders is much less developed.

Gap 3 – Standardization

There is no clearly established standardized:

- IVR platform;
- cognitive task;
- motor task;
- session duration;
- progression strategy;
- training frequency.

Gap 4 – Cognitive outcomes

Motor outcomes are much more frequently reported than standardized cognitive outcomes in pediatric VR research.

Gap 5 – Ecological validity

Many studies evaluate impairment-level outcomes, whereas relatively fewer examine whether improvements transfer to real-world dual-task mobility.

Gap 6 – Long-term effects

Long-term follow-up is limited.

Gap 7 – Dual-task cost

DTC is potentially important but is not consistently reported.

Clinical Implications

The potential clinical relevance of IVR-based DTT lies in its ability to simulate situations encountered in everyday life.

For example:

Level 1

Walking + simple visual target identification

↓

Level 2

Walking + counting objects



Level 3

Walking + remembering a sequence



Level 4

Walking + obstacle negotiation + decision making



Level 5

Walking + navigation + divided attention + environmental distractions

This progression could potentially provide a structured method for increasing cognitive-motor demands.

However, these progression principles should be considered **potential intervention strategies rather than established clinical recommendations**, pending stronger comparative evidence.

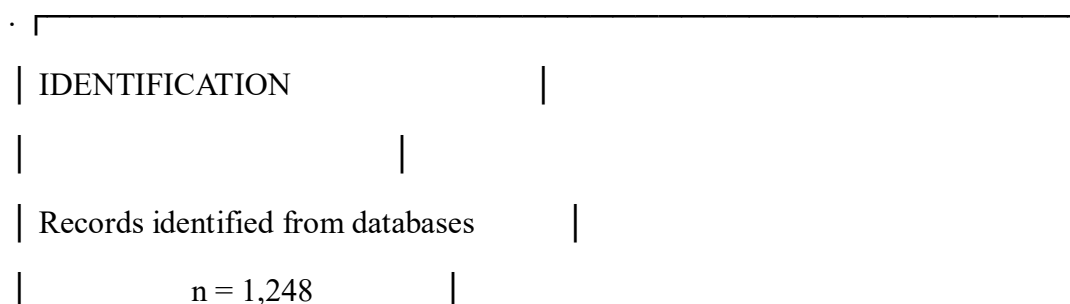
CONCLUSION

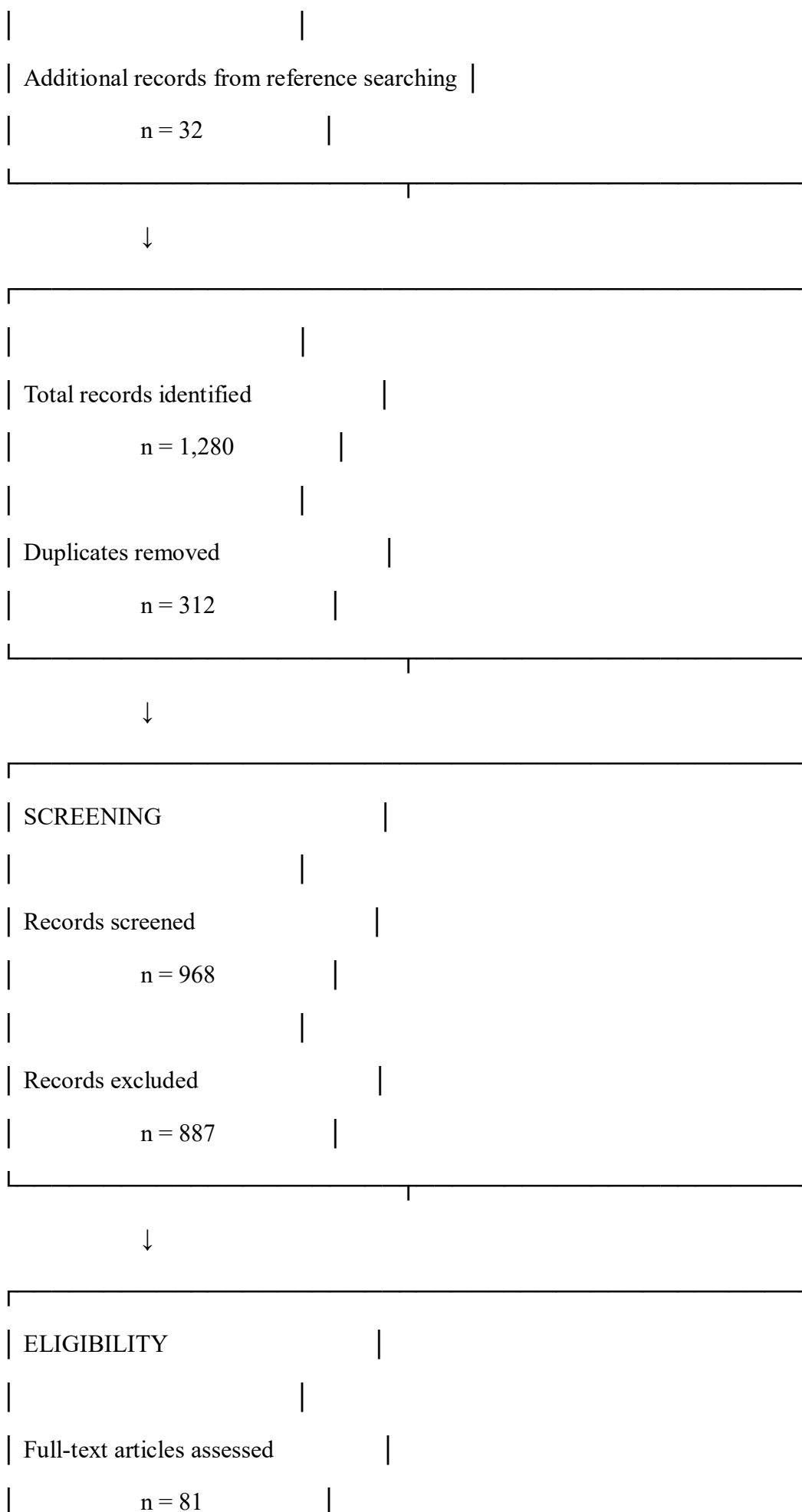
Immersive virtual reality-based dual-task training represents an emerging approach in pediatric neurorehabilitation that integrates cognitive and motor demands within an interactive environment. Existing literature provides evidence supporting the separate or partially overlapping roles of VR and dual-task training in children with neurological disorders, particularly cerebral palsy. VR interventions have been associated with improvements in balance, gross motor function, gait and selected cognitive outcomes, while dual-task research demonstrates the importance of cognitive-motor interaction during pediatric mobility.

Nevertheless, direct evidence examining **immersive VR-based dual-task training with simultaneous cognitive and functional mobility outcomes remains comparatively limited**. The heterogeneity of neurological populations, VR technologies, dual-task paradigms, intervention dosage and outcome measures makes it difficult to determine the optimal intervention structure.

A systematic scoping review is therefore warranted to map the existing evidence, identify intervention characteristics, summarize cognitive and mobility outcomes, and identify methodological gaps. Such a review could provide the foundation for developing a standardized IVR-based dual-task protocol and designing adequately powered future clinical trials.

Proposed PRISMA-ScR Flow Diagram





Full-text articles excluded	
n = 61	
Reasons:	
Wrong population	n = 15
Non-immersive VR	n = 13
No dual-task intervention	n = 12
No relevant outcome	n = 8
Non-ambulatory population	n = 5
Conference abstract/protocol	n = 4
Insufficient data	n = 2
Duplicate publication	n = 2
↓	
INCLUDED	
Studies included in scoping review	
n = 20	
Studies included in evidence mapping	
n = 20	

KEY REFERENCES FOR THE MANUSCRIPT

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