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Task-Based fNIRS for Screening Cognitive Impairment: An Umbrella Review of Task Paradigms, Operational Tactics, and Feasibility

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ADMINISTRATIVE INFORMATION**Support** - Funded by Hong Kong Centre for Neurodegenerative Diseases Limited (Ref: DON250002) .**Review Stage at time of this submission** - Preliminary searches.**Conflicts of interest** - None declared.**INPLASY registration number:** INPLASY2026100063**Amendments** - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 13 October 2026 and was last updated on 13 October 2026.**INTRODUCTION**

Review question / Objective This umbrella review aims to systematically synthesize evidence from existing systematic reviews and meta-analyses on task-based functional near-infrared spectroscopy (fNIRS) for screening cognitive impairment. The review will address the following core questions: In the context of screening for cognitive impairment (including mild cognitive impairment and dementia), do diagnostic accuracy and feasibility differ across task paradigms (e.g., verbal fluency, working memory, Stroop task)? How do current operational tactics—including channel configuration, signal processing pipelines, classification algorithm selection, and threshold determination—influence screening feasibility and performance? Furthermore, this review will evaluate the clinical feasibility of task-based fNIRS as a screening tool for cognitive impairment, identify methodological limitations and research gaps in the current evidence base, and provide a foundation for developing standardized

protocols for future research and clinical translation.

Condition being studied a. Human participants with:

- i. mild cognitive impairment (MCI);
- ii. dementia;
- iii. Alzheimer's disease;
- iv. cognitive impairment; or
- v. cognitive decline.

b. Reviews including mixed populations (e.g., cognitively healthy older adults and people with MCI/dementia) will be included only if findings for the cognitively impaired group are reported separately or can be clearly extracted.

METHODS

Search strategy Keywords search : "systematic review or meta-analysis or overview of reviews or evidence synthesis or umbrella review" and "functional near-infrared spectroscopy or fNIRS" and "mild cognitive impairment or MCI or dementia

or Alzheimer's disease or cognitive impairment or cognitive decline" and "Task paradigm or Verbal fluency or VFT or n-back or 1-back or stroop or Executive function or Cognitive load or Resting state"

From the Database as follows: Cochrane Library, PubMed, Medline Ultimate and Web of Science.

Participant or population Human participants with:

- i.mild cognitive impairment (MCI);
- ii.dementia;
- iii.Alzheimer's disease;
- iv.cognitive impairment; or
- v.cognitive decline. .

Intervention 4.Cognitive task paradigm

a.The review includes fNIRS assessment performed during at least one cognitive task paradigm, such as:

- i.verbal fluency task (VFT);
- ii.n-back task;
- iii.Stroop task;
- iv.executive-function tasks;
- v.cognitive-load tasks; or
- vi.resting-state paradigms, if they are explicitly considered as part of cognitive assessment in the review. .

Comparator Not applicable.

Study designs to be included a.Systematic reviews, meta-analyses, umbrella reviews, evidence syntheses, or reviews of reviews. To be considered systematic, a review should report a reproducible search strategy and explicit eligibility criteria and/or methods for selecting included studies. .

Eligibility criteria Inclusion criteria

Studies will be included if they meet all of the following criteria:

1.Study design

a.Systematic reviews, meta-analyses, umbrella reviews, evidence syntheses, or reviews of reviews.

b.To be considered systematic, a review should report a reproducible search strategy and explicit eligibility criteria and/or methods for selecting included studies.

2.Population

a.Human participants with:

- i.mild cognitive impairment (MCI);
- ii.dementia;
- iii.Alzheimer's disease;
- iv.cognitive impairment; or
- v.cognitive decline.

b.Reviews including mixed populations (e.g., cognitively healthy older adults and people with MCI/dementia) will be included only if findings for the cognitively impaired group are reported separately or can be clearly extracted.

3.Index method/exposure

a.The review evaluates or includes studies using functional near-infrared spectroscopy (fNIRS) to assess brain activity, cortical hemodynamic responses, oxygenated hemoglobin (HbO), deoxygenated hemoglobin (HbR), or total hemoglobin during cognitive assessment.

4.Cognitive task paradigm

a.The review includes fNIRS assessment performed during at least one cognitive task paradigm, such as:

- i.verbal fluency task (VFT);
- ii.n-back task;
- iii.Stroop task;
- iv.executive-function tasks;
- v.cognitive-load tasks; or
- vi.resting-state paradigms, if they are explicitly considered as part of cognitive assessment in the review.

5.Outcomes

a.The review reports fNIRS-related outcomes relevant to cognitive impairment, including differences in cerebral activation, prefrontal cortical activation, functional connectivity, hemodynamic response, diagnostic performance, classification accuracy, or associations with cognitive performance.

6.Publication characteristics

a.Full-text articles published in peer-reviewed journals.

b.Articles written in English [if this is your intended language restriction].

c.No publication-date restriction will be applied [or state your specific date range, if applicable].

Exclusion criteria

Studies will be excluded if they meet any of the following criteria:

1.Ineligible publication type

a.Primary/individual empirical studies, including cross-sectional, case-control, cohort, diagnostic-accuracy, or intervention studies that are not systematic reviews or meta-analyses.

b.Narrative reviews, scoping reviews without systematic search methods, editorials, commentaries, letters, conference abstracts, protocols, dissertations, theses, book chapters, and study registrations.

2.Ineligible population

a.Reviews focused exclusively on healthy individuals, psychiatric disorders, stroke, traumatic brain injury, Parkinson's disease, autism spectrum disorder, or other neurological conditions without

separately reported data for MCI, dementia, Alzheimer's disease, or cognitive impairment.

3. Ineligible measurement method

a. Reviews using neuroimaging or neurophysiological methods other than fNIRS only, such as fMRI, EEG, PET, SPECT, MEG, or structural MRI, with no fNIRS findings.

b. Studies using conventional near-infrared spectroscopy that do not measure functional brain activation or hemodynamic changes related to a cognitive task, where this can be determined.

4. Ineligible task/context

a. Reviews in which fNIRS is not used during a cognitive task or resting-state assessment relevant to cognitive functioning.

b. Reviews focused solely on motor, gait, balance, rehabilitation, or physical-exercise tasks without cognitive-task outcomes relevant to cognitive impairment.

5. Ineligible outcomes

a. Reviews that do not report fNIRS findings relevant to cognitive impairment, cognitive performance, cerebral activation, or diagnostic/classification outcomes.

6. Duplicate or overlapping records

a. Duplicate publications will be removed.

b. Where multiple reports of the same review are identified, the most complete and most recent version will be retained. Older versions may be used only for supplementary information if necessary.

Information sources electronic databases: Cochrane Library; PubMed; Medline Ultimate and Web of Science; contact with authors; hand searching.

Main outcome(s) The primary outcome will be the diagnostic accuracy of task-based fNIRS for screening cognitive impairment (including mild cognitive impairment and dementia), expressed as pooled sensitivity, specificity, and area under the curve (AUC), along with measures of heterogeneity, when reported in the included systematic reviews and meta-analyses. Where available, accuracy estimates will be extracted and compared across task paradigms (e.g., verbal fluency, working memory, Stroop task) and operational tactics (e.g., channel configuration, signal processing pipelines, classification algorithms, and threshold determination).

Additional outcome(s) Task paradigm characteristics – types of cognitive tasks employed, their administration protocols, and reported feasibility (e.g., completion rates, tolerability, time burden).

Operational tactics – preprocessing and signal processing methods, channel/region-of-interest selection, feature extraction approaches, classification algorithms, and cutoff thresholds used.

Feasibility and acceptability – practicality of implementation in screening settings, including portability, cost, training requirements, and participant tolerability.

Methodological quality and risk of bias – as reported in the included reviews (e.g., AMSTAR 2 ratings, QUADAS-2 assessments) and limitations noted by review authors.

Research gaps – unresolved issues regarding standardization, validation, and clinical translation of task-based fNIRS for cognitive impairment screening.

Quality assessment / Risk of bias analysis The methodological quality of all included systematic reviews and meta-analyses will be independently assessed using the AMSTAR 2 (Assessment of Multiple Systematic Reviews 2) tool. This instrument is specifically designed to appraise systematic reviews of healthcare interventions, including both randomised and non-randomised studies, and is recommended for overviews of systematic reviews.

Strategy of data synthesis Given the nature of an umbrella review, the synthesis will follow a structured approach that combines quantitative pooling where appropriate with rigorous qualitative summary where meta-analytical integration is not feasible. The synthesis will be conducted in the following stages:

1. Characteristics of included reviews

A detailed summary table will be constructed to describe the characteristics of each included systematic review and meta-analysis, including: authors and year, number and design of primary studies included, population (MCI, dementia subtypes, mixed), task paradigms assessed, fNIRS operational tactics reported, outcomes measured, and funding sources.

2. Quantitative synthesis (where feasible)

If included reviews report sufficient and comparable diagnostic accuracy data, pooled estimates of sensitivity, specificity, and AUC will be extracted and, where appropriate, re-analysed or summarised narratively. Where multiple reviews address the same task paradigm or operational tactic, results will be tabulated side-by-side to

allow direct comparison. Overlapping primary studies across reviews will be identified and documented; if the degree of overlap is substantial, a corrected covered area (CCA) will be calculated and reported to quantify redundancy.

3. Qualitative/narrative synthesis

Due to anticipated heterogeneity in task paradigms, populations, fNIRS devices, channel configurations, and classification methods, a narrative synthesis will be the primary approach. Findings will be organised thematically according to the review's core questions:

Task paradigms: comparative accuracy and feasibility across verbal fluency, working memory, Stroop, and other tasks.

Operational tactics: influence of channel layout, preprocessing pipelines, feature extraction, classification algorithms, and threshold selection on screening performance.

Feasibility: practical considerations including portability, cost, administration time, training requirements, and participant tolerability.

Methodological limitations and research gaps: recurring weaknesses and unresolved issues identified across reviews.

4. Certainty of evidence

The certainty of evidence will be evaluated using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach adapted for diagnostic accuracy, where applicable. Confidence in the findings will be rated as high, moderate, low, or very low, taking into account risk of bias (AMSTAR 2 ratings), inconsistency, indirectness, imprecision, and publication bias. For diagnostic accuracy, additional domains such as patient selection, index test, reference standard, and flow/timing will be considered.

5. Presentation of results

Results will be presented using summary-of-findings tables, evidence maps, and forest plots where quantitative pooling is possible. A narrative synthesis will accompany these to interpret the findings in the context of clinical feasibility and translational potential. Research gaps and recommendations for standardising task-based fNIRS protocols will be explicitly outlined.

6. Sensitivity and subgroup considerations

Where data permit, subgroup analyses will explore potential sources of heterogeneity, including

cognitive impairment severity (MCI vs. dementia), task type, fNIRS device/technology, and geographic or clinical setting. Sensitivity analyses will examine the impact of excluding reviews with critically low methodological quality (AMSTAR 2) on the overall conclusions.

Subgroup analysis Subgroup analysis:

Where data permit, subgroup analyses will be conducted to explore potential sources of heterogeneity and to examine whether the diagnostic accuracy and feasibility of task-based fNIRS for cognitive impairment screening differ across clinically and methodologically relevant strata. The following subgroup analyses are planned a priori:

1. Cognitive impairment severity and subtype

Mild cognitive impairment (MCI) versus dementia (including Alzheimer's disease, vascular dementia, frontotemporal dementia, and Lewy body dementia).

Amnesic versus non-amnesic MCI, where reported.

Mixed or undifferentiated cognitive impairment versus specific diagnostic categories.

2. Task paradigm

Verbal fluency tasks (phonemic vs. semantic).

Working memory tasks (e.g., n-back, digit span).

Executive function tasks (e.g., Stroop, Trail Making Test).

Other paradigms (e.g., motor, language, or multimodal tasks).

3. Operational tactics

Channel configuration and region of interest (prefrontal cortex only vs. multi-region coverage).

Signal processing pipelines (e.g., motion artefact correction methods, haemodynamic response function models).

Feature extraction approaches (e.g., mean oxygenated haemoglobin, slope, connectivity metrics).

Classification algorithms (e.g., SVM, random forest, deep learning) and threshold determination methods.

4. Technical and device-related factors

fNIRS device type (continuous wave, frequency-domain, time-domain).

Number of channels and spatial resolution.

Portable/wearable versus traditional laboratory-based systems.

5. Study and review-level characteristics

Geographic region and clinical setting (community, primary care, specialist memory clinic).

Reference standard used for diagnosis (clinical criteria vs. neuropsychological battery vs. biomarker-confirmed).

Methodological quality of included reviews (AMSTAR 2 rating: high/moderate vs. low/critically low).

Publication year, to assess temporal trends in technology and methodology.

6. Population characteristics

Age groups (e.g., older adults ≥ 65 years vs. younger populations).

Educational level and cultural/linguistic background, where reported.

Comorbidities that may affect fNIRS signals (e.g., psychiatric disorders, cerebrovascular disease).

Subgroup analyses will be performed only when a sufficient number of reviews or primary studies contribute data to each stratum (typically at least two to three reviews per subgroup). Given the anticipated heterogeneity and the umbrella review design, subgroup findings will be interpreted cautiously and primarily narratively, with formal meta-regression considered only if adequate quantitative data are available. Any subgroup analyses that were not pre-specified will be clearly labelled as exploratory.

Sensitivity analysis Sensitivity analyses will be conducted to assess the robustness of the review findings and to determine whether conclusions are influenced by methodological decisions, study characteristics, or the quality of the included

evidence. The following sensitivity analyses are planned:

1. Methodological quality of included reviews

Re-analysis excluding reviews rated as "Critically Low" quality on AMSTAR 2, to examine whether conclusions change when only moderate- to high-quality reviews are considered.

Separate analyses restricted to reviews rated "High" or "Moderate" confidence, to assess the impact of methodological rigour on pooled estimates and narrative conclusions.

2. Overlap of primary studies

Sensitivity analysis excluding reviews with substantial primary study overlap (e.g., CCA $> 15\%$), to evaluate whether redundancy across reviews distorts the synthesis.

Comparison of findings before and after applying overlap corrections, where quantitative pooling is feasible.

3. Diagnostic accuracy estimates

Sensitivity analyses restricted to reviews using biomarker-confirmed or neuroimaging-confirmed reference standards versus those relying on clinical or neuropsychological criteria alone.

Analyses excluding reviews with high risk of bias in patient selection, index test, or reference standard domains (QUADAS-2), where reported.

4. Task paradigm and operational tactics

Re-analysis excluding studies using non-standard or poorly described task paradigms, to assess the impact of task heterogeneity.

Sensitivity analyses restricted to reviews reporting standardised preprocessing pipelines or validated classification algorithms.

5. Publication and reporting bias

Comparison of pooled estimates from reviews that formally assessed publication bias (e.g., funnel plot, Egger's test) versus those that did not.

Where feasible, trim-and-fill or selection models will be applied to evaluate the potential impact of small-study effects, if primary data can be reconstructed.

6. Population and setting

Sensitivity analyses excluding reviews focused exclusively on atypical populations (e.g., psychiatric comorbidities, traumatic brain injury) that may not be representative of typical cognitive impairment screening settings.

Analyses restricted to community-based or primary care settings versus specialist memory clinic populations.

7. Temporal trends

Sensitivity analyses excluding older reviews (e.g., published before 2015) to account for advances in fNIRS technology, signal processing, and diagnostic criteria.

8. Language and geographic restrictions

If any language or geographic restrictions are applied during screening, sensitivity analyses will assess their impact on the overall findings.

Results of all sensitivity analyses will be reported transparently, and any changes in the direction, magnitude, or statistical significance of findings will be discussed in the context of the review's conclusions. Where sensitivity analyses are not feasible due to insufficient data, this will be explicitly stated as a limitation.

Country(ies) involved HongKong, China.

Keywords Task-based fNIRS; functional near-infrared spectroscopy; cognitive impairment; mild cognitive impairment; dementia; umbrella review; systematic review; screening; diagnostic accuracy; task paradigms;.

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