Supplementary Materials

Supplementary Table 1. Characteristics of Feature Extraction and Input Variables Across Studies.

Study	Type of cognitive disorder	Feature extraction	Input variables
Davis et al, (2015) [33]	AD	500 properties of the drawing, including traditional outcome measures and novel behavioral measures such as pauses and pen speed	Not specified
Garre-Olmo et al. (2017) [29]	MCI	1) Pressure; 2) Time; 3) Speed; 4) Acceleration; 5) Energy; 6) Complexity	Complexity
Müller et al. (2017) [22]	MCI	Time-in-air; Time-on-surface; Total-time	Time-in-air
	AD	Time-in-air, time-on-surface, total-time	Time-in-air
Müller et al. (2019) [36]	MCI	Time in air; Time on surface; Total time; Velocity; Pressure; Pressure/velocity relation; Strokes per minute; Time not painting; Pen-up stroke length; Pen-up/pen-down relation; CDT score	Time in air; Time not painting; CDT score
	AD		Time in air; CDT score
Zhang (2021) [37]	MCI	Thinking time; Drawing time; Total completion time; Post-clockface latency; First-hand latency; Second-hand latency; Drawing speed; Minute-hand/hour-hand; Strokes per minute	Second-hand latency; Minute-hand/hour-hand; Strokes per minute
Zheng et al. (2021) [31]	AD	The analysis involved both spatial and temporal features, and a total of 109 clock-related features were extracted.	69 spatial features, 40 temporal features, and 3 demographic characteristics. Age, education and gender
Lü (2022) [40]	MCI	Total time for clock-drawing, Drawing time, Thinking time,Percentage of drawing time, Percentage of thinking time, Total number of strokes, Minimum circle area, Average speed, Number of strokes per minute, Average stroke length, Clock-face latency, First-hand latency, Second-hand latency	Total number of strokes; Number of strokes per minute

Liu (2023) [38]	AD	CNN image features (AlexNet); 11 drawing process features: total number of strokes, number of strokes per minute, length of the longest stroke, average stroke length, pen-down time, thinking time, total completion time, average stroke drawing speed, area of the minimum circum-circle, area of the minimum circum-rectangle, and the position of the graphic center	PCA-reduced CNN features; 11 drawing process features
Li et al. (2024) [35]	MCI	Five features related to hand motor function were extracted, including time, stroke, frequency, score, and sequence.	Score; Number unpainted time; Pointer unpainted time Number painting time; Number unpainted time; Number painting frequency (augmented dCDT)
Um Din et al. (2024) [34]	MCI	score	score
Chen et al. (2025) [39]	MCI	27 features were extracted, including variables considered relevant to clock face, digit, and hand placement, as well as think and ink times. Clinical variables: age, sex, years of education, history of smoking and alcohol consumption, and medical history of stroke, hypertension, diabetes, and hyperlipidemia.	For the standalone dCDT, 16 parameters were included: clock-face drawing time, velocity of hour hand, drawing time of hour hand, length of minute hand, length ratio of hour and minute hands, drawing time of digits, percentage of correct digits, percentage of correct digit position, total think time, total ink time, total completion time, first stroke latency, total number of strokes,maximum stroke length, number of strokes per minute,and average think time.

			For the augmented dCDT, 16 parameters were included: clock-face drawing time, velocity of hour hand, drawing time of hour hand, length of minute hand, length ratio of hour and minute hands, drawing time of digits, percentage of correct digits, percentage of correct digit position, total think time, total ink time, total completion time, first stroke latency, total number of strokes,maximum stroke length, number of strokes per minute,and average think time. Clinical variables: age, gender, education level, stroke history, drinking history
Zhang et al. (2025) [41]	MCI	27 feature parameters were collected by the device, including stroke length, pause time, drawing time, speed, number, clock face area, among others.	Average time in air；Total time latency；Word recall score；Pre-second-hand latency；Time on surface；Pre-first-hand latency；Strokes per minute；Average velocity；Total time of 12 digits
Wu et al. (2025) [30]	MCI	score	score

Notes: References are listed in the main manuscript.

Abbreviations: dCDT, Digital Clock Drawing Test; AD, Alzheimer's disease; MCI, Mild Cognitive Impairment; CNN, Convolutional Neural Network.

Supplementary Table 2. Sensitivity analysis of the standalone dCDT for MCI diagnosis after sequential Study exclusion.

Study excluded	Sensitivity (95% CI)	Specificity (95% CI)	LR+ (95% CI)	LR- (95% CI)	DOR (95% CI)	AUC (95% CI)
Garre-Olmo et al. (2017) [29]	0.759 (0.669 - 0.830)	0.745 (0.660 - 0.815)	2.978 (2.076 - 4.273)	0.324 (0.220 - 0.477)	9.198 (4.525 - 18.699)	0.818 (0.782 - 0.849)
Müller et al. (2017) [22]	0.760 (0.666 - 0.834)	0.756 (0.669 - 0.826)	3.114 (2.124 - 4.564)	0.317 (0.212 - 0.476)	9.809 (4.644 - 20.717)	0.825 (0.789 - 0.855)
Müller et al. (2019) [36]	0.746 (0.657 - 0.818)	0.752 (0.657 - 0.828)	3.008 (2.022 - 4.475)	0.338 (0.232 - 0.475)	8.896 (4.285 - 18.468)	0.814 (0.778 - 0.846)
Zhang (2021) [37]	0.767 (0.673 - 0.840)	0.744 (0.655 - 0.816)	2.994 (2.058 - 4.355)	0.314 (0.207 - 0.475)	9.544 (4.502 - 20.234)	0.821 (0.785 - 0.852)
Lü (2022) [40]	0.760 (0.666 - 0.834)	0.749 (0.661 - 0.821)	3.033 (2.077 - 4.429)	0.320 (0.213 - 0.480)	9.477 (4.508 - 19.926)	0.821 (0.785 - 0.852)
Li et al. (2024) [35]	0.747 (0.660 - 0.818)	0.741 (0.650 - 0.815)	2.880 (2.009 - 4.128)	0.341 (0.239 - 0.488)	8.437 (4.315 - 16.497)	0.809 (0.772 - 0.841)
Um Din et al. (2024) [34]	0.769 (0.673 - 0.843)	0.771 (0.696 - 0.832)	3.357 (2.355 - 4.786)	0.300 (0.199 - 0.452)	11.206 (5.450 - 23.039)	0.836 (0.801 - 0.866)
Chen et al. (2025) [39]	0.789 (0.713 - 0.849)	0.731 (0.648 - 0.801)	2.936 (2.072 - 4.159)	0.288 (0.193 - 0.430)	10.176 (4.923 - 21.034)	0.829 (0.793 -0.859)
Wu et al. (2025) [30]	0.787 (0.718 - 0.842)	0.780 (0.716 - 0.833)	3.569 (2.700 - 4.719)	0.274 (0.202 - 0.370)	13.038 (7.825 - 21.724)	0.851 (0.817 - 0.879)
Non	0.765 (0.691 - 0.818)	0.752 (0.673 - 0.817)	3.084 (2.193 - 4.337)	0.312 (0.217 - 0.449)	9.883 (5.071 - 19.263)	0.825 (0.790 - 0.856)

Notes: References are listed in the main manuscript.

Abbreviations: dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment; LR+, Positive Likelihood Ratio; LR-, Negative Likelihood Ratio; DOR, diagnostic odds ratio; AUC, Area Under The Summary Receiver Operating Characteristic Curve.

Supplementary Table 3. PRISMA reporting checklist.

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Pages 2-3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Pages 11-12
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 11
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 11
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 12
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 12
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 12
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 12
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Pages 12-13
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 13
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Pages 11-13
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 13
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 13
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 13

Section and Topic	Item #	Checklist item	Location where item is reported
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Pages 13-14
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Pages 13-14
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Pages 12-14
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Pages 13-14
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 4 Fig. 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 4 Fig. 1
Study characteristics	17	Cite each included study and present its characteristics.	Pages 4-5 Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 5 Figure 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Pages 5-7 Table 2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 5 Fig. 2
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Pages 5-7 Table 2 Fig. 3-4 Supplementary Fig. 1-10
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Pages 6-7 Table 2
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 7 Supplementary Table 2
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Pages 5-6 Table 2
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Pages 5-7 Table 2

Section and Topic	Item #	Checklist item	Location where item is reported
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Pages 7-9
	23b	Discuss any limitations of the evidence included in the review.	Pages 9-10
	23c	Discuss any limitations of the review processes used.	Pages 9-10
	23d	Discuss implications of the results for practice, policy, and future research.	Page 10
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 11
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Not applicable
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not applicable
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 21
Competing interests	26	Declare any competing interests of review authors.	Page 21
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page 14

Supplemental Table 4. Search strategies.

Web of Science
1. ((((((((((TS=(Alzheimer Disease)) OR TS=(Alzheimer*)) ORTS=(AD)) OR TS=(Alzheimer's Disease)) OR TS=(DAT)) ORTS=(Cognitive Dysfunction)) OR TS=(Mild Cognitive Impairment*)) OR TS=(MCI)) OR TS=(Cognitive Disorder*))OR TS=(Cognitive Impairment*)) OR TS=(Cognitive Decline*)
2. ((((TS=(dCDT))OR TS=(CDT))OR TS=(digital clock))OR TS=(clock drawing)) OR TS=(clock test)
3. ((((((TS=(sensitiv*)) OR TS=(sensitivity and specificity)) ORTS=(predictive)) OR TS=(value*)) OR TS=(predictive valueof tests)) OR TS=(accuracy*)) OR TS=(diagnostic)
4. 1 and 2 and 3
Embase
1. 'alzheimer disease'/exp OR alzheimer*:ti,ab OR ad:ti,ab OR 'alzheimer* disease':ti,ab OR dat:ti,ab OR 'cognitive defect'/exp OR 'mild cognitive impairment*':ti,ab OR mci:ti,ab OR 'cognitive disorder*':ti,ab OR 'cognitive impairment*':ti,ab OR 'cognitive decline*':ti,ab
2. 'clock drawing test'/exp OR dcdt:ti,ab OR 'clock drawing':ti,ab OR 'clock test':ti,ab OR cdt:ti,ab OR 'digital clock':ti,ab
3. sensitiv*:ti,ab OR 'sensitivity and specificity':ti,ab OR 'predictive value of tests':ti,ab OR predictive:ti,ab OR value*:ti,ab OR accuracy*:ti,ab OR diagnostic*:ti,ab
4. 1 and 1 and 3
Pubmed
1. ((("Alzheimer Disease"[Mesh]) OR ((((Alzheimer*[Title/Abstract]) OR (AD[Title/Abstract])) OR (Alzheimer's Disease[Title/Abstract])) OR (DAT[Title/Abstract]))) OR ("Cognitive Dysfunction"[Mesh])) OR (((((Mild Cognitive Impairment*[Title/Abstract]) OR (MCI[Title/Abstract])) OR (Cognitive Disorder*[Title/Abstract])) OR (Cognitive Impairment*[Title/Abstract])) OR (Cognitive Decline*[Title/Abstract]))
2. ((((dCDT[Title/Abstract]) OR (CDT[Title/Abstract])) OR (digital clock[Title/Abstract])) OR (clock drawing[Title/Abstract])) OR (clock test[Title/Abstract])
3. sensitiv*[Title/Abstract] OR sensitivity and specificity[MeSH Terms] OR (predictive[Title/Abstract] AND value*[Title/Abstract]) OR predictive value of tests[MeSH Terms] OR accuracy*[Title/Abstract]
6. 1 and 2 and 3
PsyINFO
1. XB (Alzheimer Disease OR Alzheimer* OR AD OR Alzheimer's Disease OR DAT OR Cognitive Dysfunction OR Mild Cognitive Impairment* OR MCI OR Cognitive Disorder* OR Cognitive Impairment* OR Cognitive Decline*)
2. XB (clock drawing test OR dCDT OR clock drawing OR clock test OR CDT OR digital clock)
3. XB (sensitiv* OR sensitivity and specificity OR predictive OR value* OR predictive value of tests OR accuracy* OR diagnostic)
4. 1 and 2 and 3
IEEE Xplore
1. (((Publication Title:Mild Cognitive Impairment* OR Publication Title:MCI OR Publication

Title:Cognitive) OR (Abstract:Mild Cognitive Impairment OR Abstract:MCI OR Abstract:Cognitive))) OR ((Publication Title:Alzheimer Disease OR Publication Title:Alzheimer* OR Publication Title:AD OR Publication Title:Alzheimer's Disease OR Publication Title:DAT) OR (Abstract:Alzheimer Disease OR Abstract:Alzheimer* OR Abstract:AD OR Abstract:Alzheimer's Disease OR Abstract:DAT))

2. ("Publication Title":dCDT OR "Publication Title":CDT OR "Publication Title":digital clock OR "Publication Title":clock drawing OR “Publication Title":clock test) OR ("Abstract":dCDT OR "Abstract":CDT OR "Abstract":digital clock OR "Abstract':clock drawing OR “Abstract":clock test)

3. 1 and 2

CNKI

1. 画钟测试 + 画钟测验 + 画钟筛查 + 时钟测验 + 时钟评估 + 时钟筛查+ 钟表筛查 + 钟表测验 + 钟表评估 + CDT

2. 阿尔采默病 + 阿耳茨海默病 + 阿尔茨海默 + 阿兹海默病 + 阿兹海默氏症 + 阿兹海默症 + 阿尔兹海默病 + 轻度认知功能障碍 + 轻度认知障碍 + 轻度认知损害 + 轻度认知损伤 + 轻微认知损害 + AD + MCI

3. 1 and 2

Wanfang

1. 画钟测试 OR 画钟测验 OR 画钟筛查 OR 时钟测验 OR 时钟评估 OR 时钟筛查 OR 钟表筛查 OR 钟表测验 OR 钟表评

2. 阿尔采默 OR 阿耳茨海默 OR 阿尔茨海默 OR 阿兹海默 OR 阿尔兹海默 OR 轻度认知功能 OR 轻度认知障碍 OR 轻度认知损害 OR 轻度认知损伤 OR 轻微认知 OR 认知功能损伤

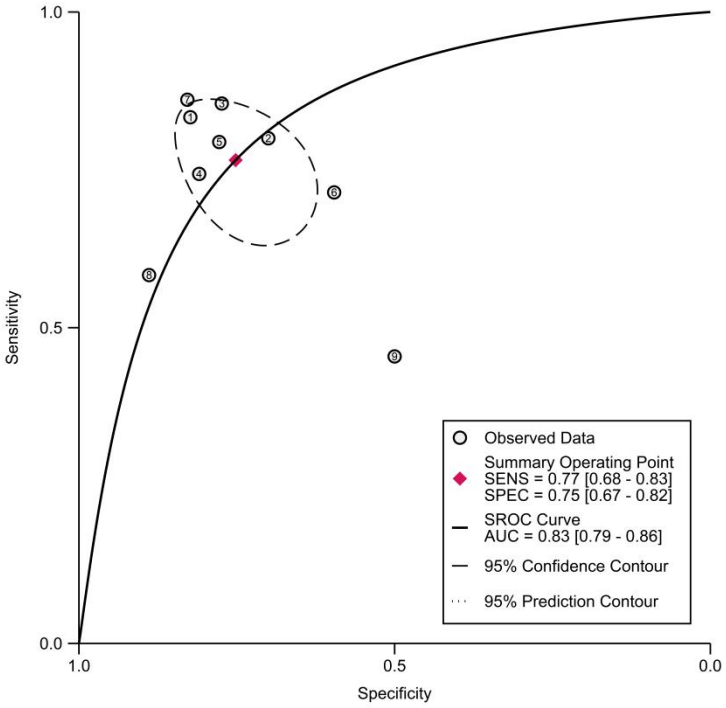
3. 1 and 2

Supplementary Table 5. Characteristics of Feature Extraction and Input Variables Across Studies.

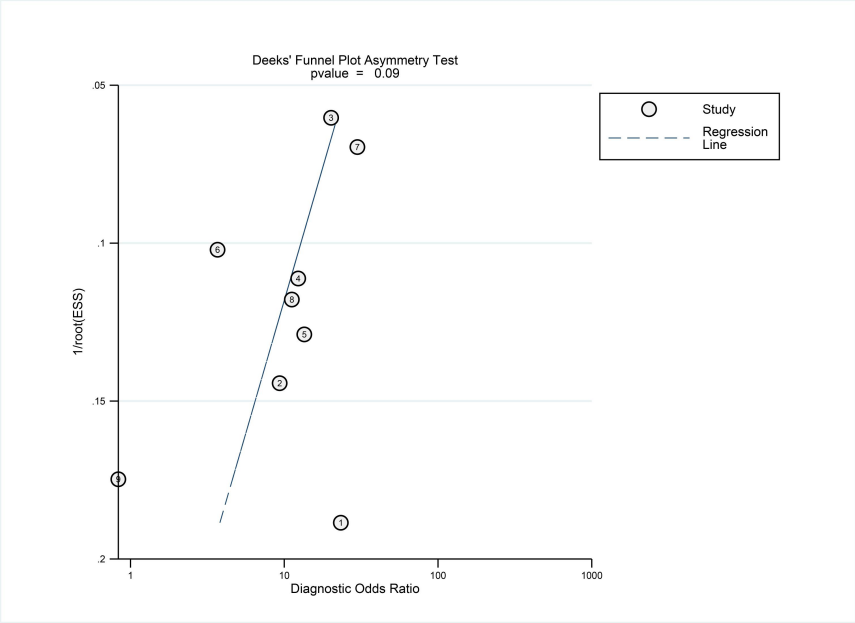
Study	Type of dCDT	Type of cognitive disorder	True Positives (OA)	False Positives (OA)	False Negatives (OA)	True Negatives (OA)
Davis et al, (2015) [33]	Standalone dCDT	AD	132	64	52	496
Garre-Olmo et al. (2017) [29]	Standalone dCDT	MCI	10	3	2	14
Müller et al. (2017) [22]	Standalone dCDT	MCI	24	6	6	14
		AD	17	2	3	18
Müller et al. (2019) [36]	Standalone dCDT	MCI	118	31	20	106
		AD	97	8	9	129
Zhang (2021) [37]	Standalone dCDT	MCI	29	8	10	34
Zheng et al. (2021) [31]	Augmented dCDT	AD	43	29	10	178
Lü (2022) [40]	Standalone dCDT	MCI	27	6	7	21
Liu (2023) [38]	Standalone dCDT	AD	12	3	3	13
Li et al. (2024) [35]	Standalone dCDT	MCI	93 (46)	17 (8)	15 (8)	82 (41)
	Augmented dCDT		95 (48)	17 (9)	13 (6)	82 (41)
Um Din et al. (2024) [34]	Standalone dCDT	MCI	35	19	14	28
Chen et al. (2025) [39]	Standalone dCDT	MCI	21 (11)	4 (2)	15 (7)	32 (16)
	Augmented dCDT		22 (11)	2 (1)	14 (7)	34 (17)
Zhang et al. (2025) [41]	Augmented dCDT	MCI	137	17	79	199
Wu et al. (2025) [30]	Standalone dCDT	MCI	5	16	6	16

Note: OA indicates overlap-adjusted 2×2 counts.

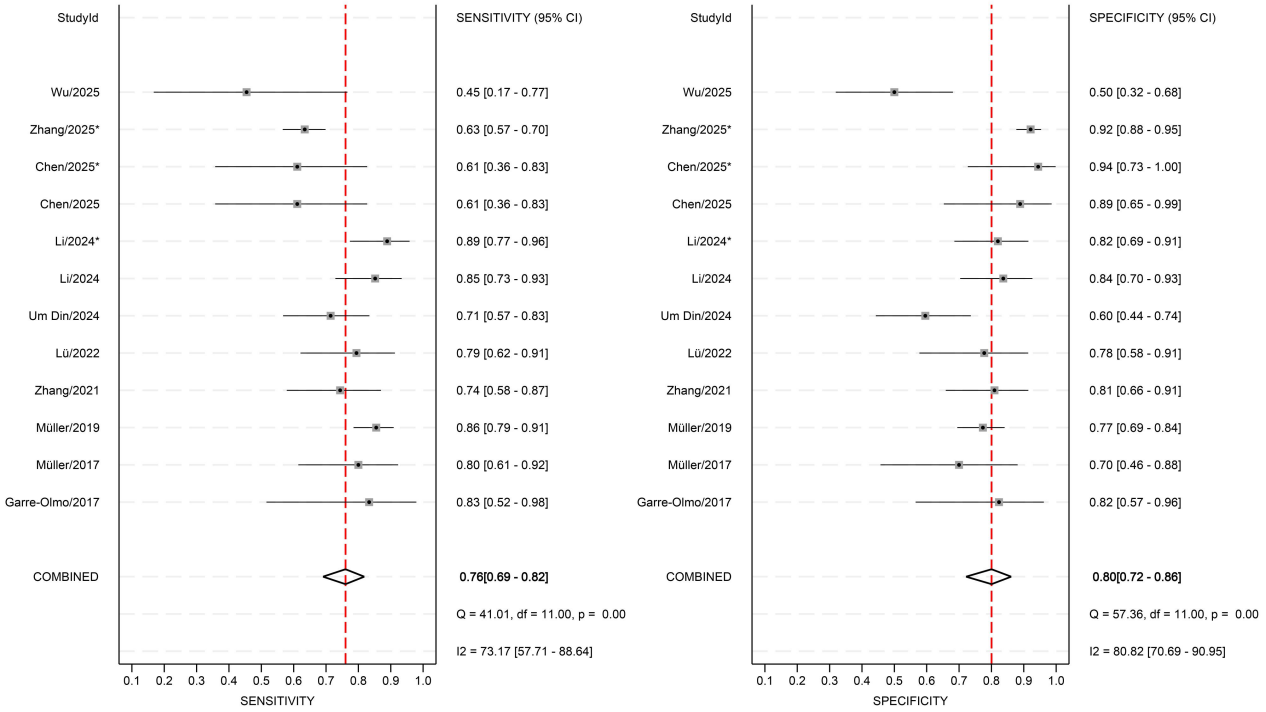
Abbreviations: dCDT, Digital Clock Drawing Test; AD, Alzheimer's disease; MCI, Mild Cognitive Impairment; OA, Overlap-Adjusted.



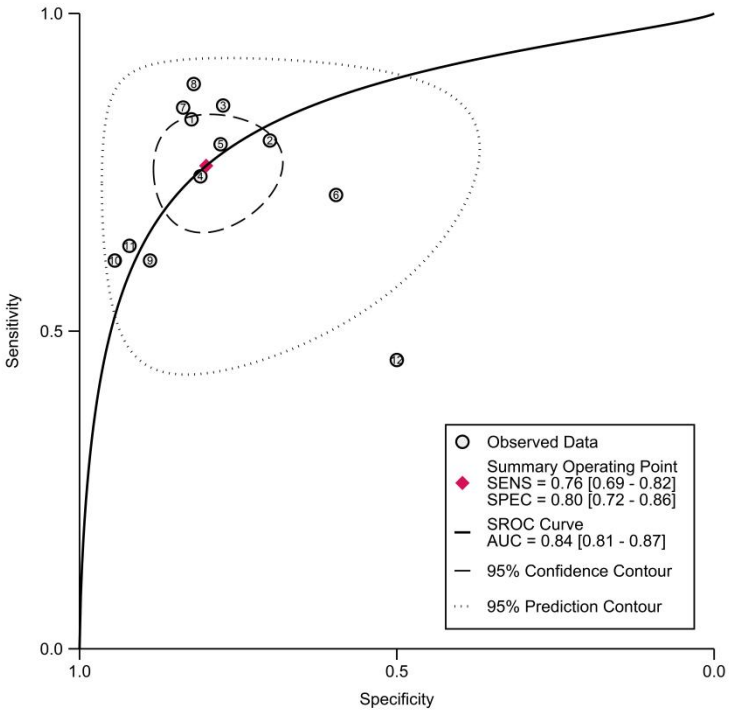
Supplementary Fig. 1. SROC curve of the standalone dCDT for MCI diagnosis. The SROC curve illustrates the diagnostic performance of the dCDT in diagnosing MCI. The AUC reflects the overall accuracy, with a higher AUC indicating better diagnostic ability. SROC, summary receiver operating characteristic curve; dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment; AUC, Area Under The Summary Receiver Operating Characteristic Curve.



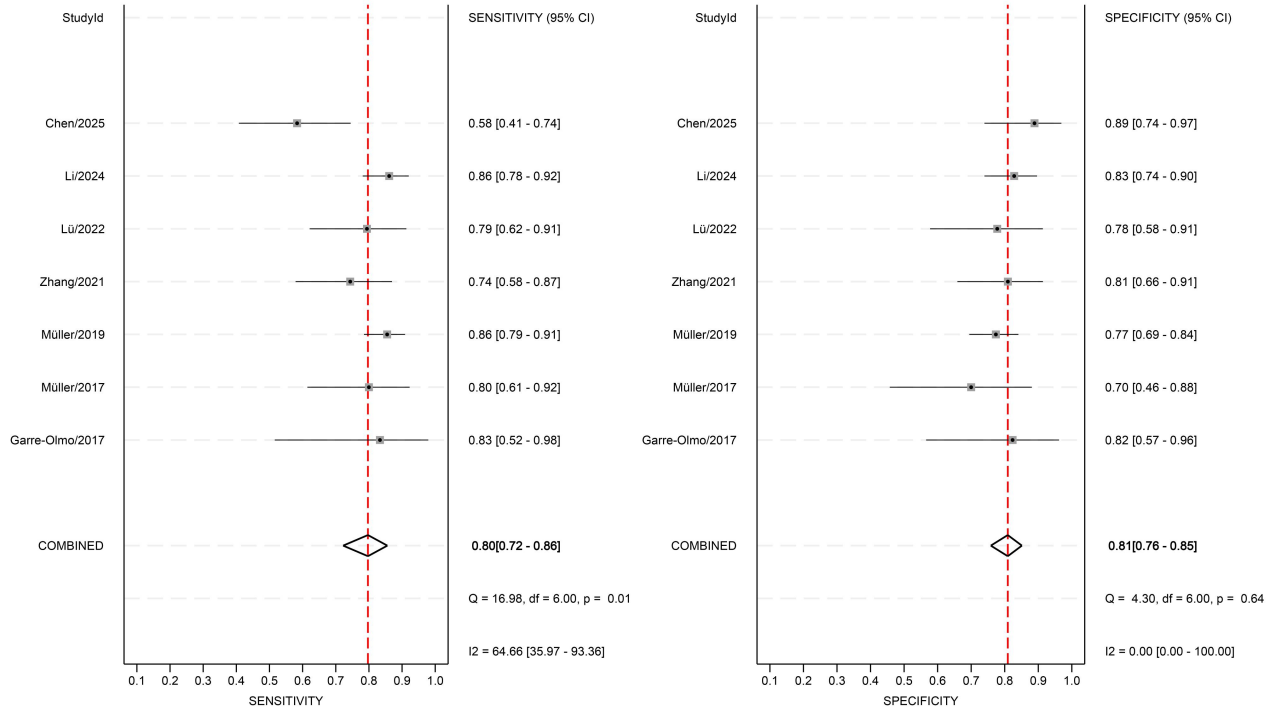
Supplementary Fig. 2. Deeks' funnel plot of publication bias in the standalone dCDT for MCI diagnosis. The Deeks' funnel plot assesses the potential publication bias in studies evaluating the diagnostic accuracy of the dCDT for MCI. Deeks' funnel plot asymmetry test yielded a p-value of 0.090, which is suggestive of small-study effects under the commonly used α = 0.10 criterion in diagnostic test accuracy meta-analyses. dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment.



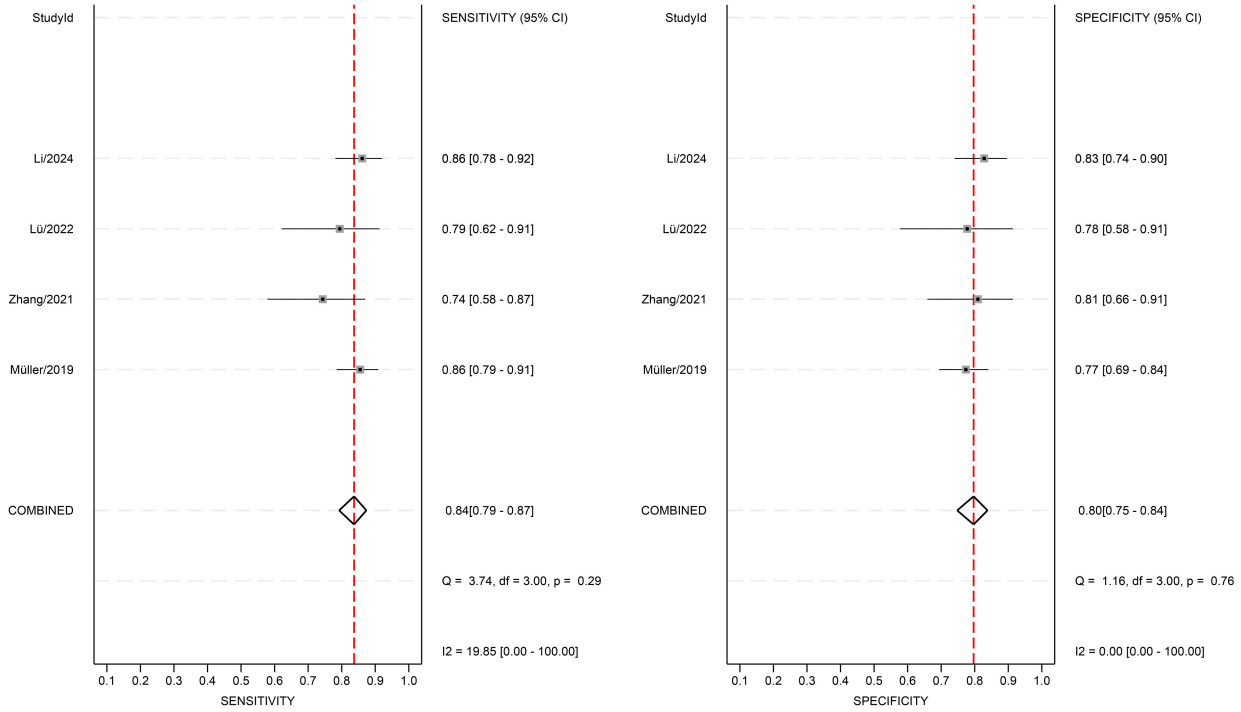
Supplementary Fig. 3. Forest plot of the diagnostic accuracy of the dCDT for MCI after incorporating the augmented dCDT studies. * the augmented dCDT studies. dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment.



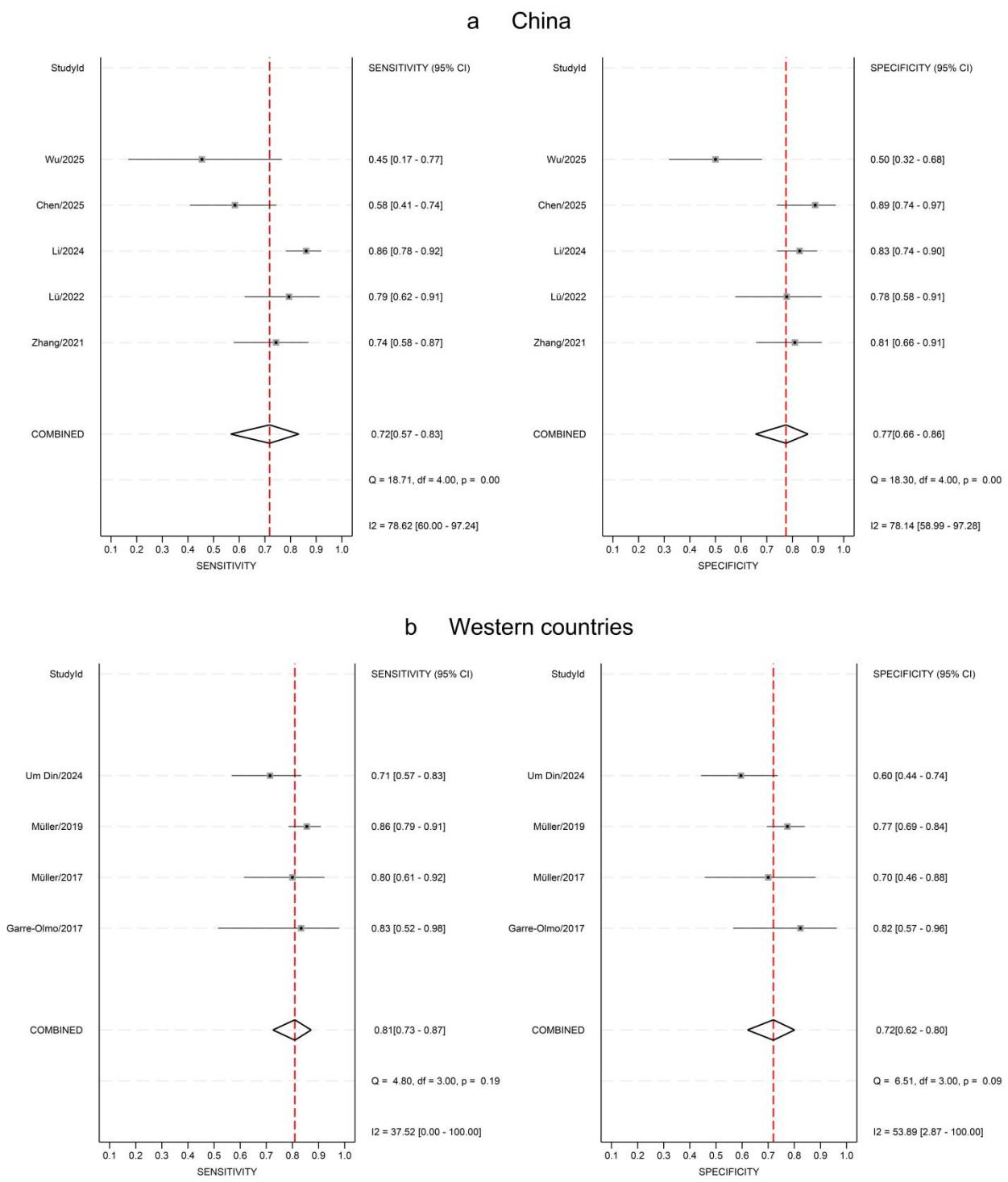
Supplementary Fig. 4. SROC curve of the dCDT for diagnosing MCI after incorporating the augmented dCDT studies. SROC, summary receiver operating characteristic curve; dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment.



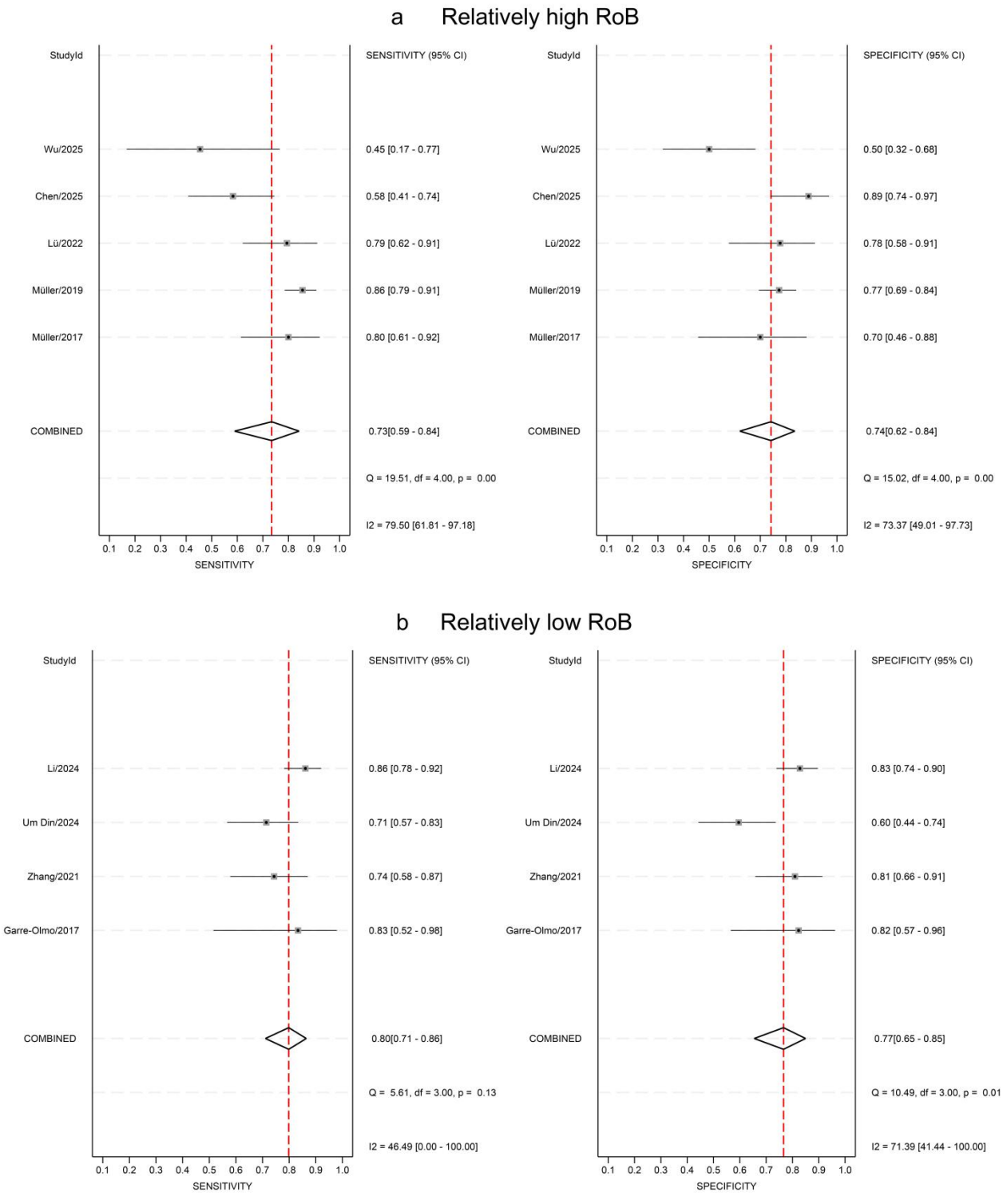
Supplementary Fig. 5. Forest plot of the diagnostic accuracy of the standalone dCDT for MCI in studies employing algorithm-based approaches. dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment.



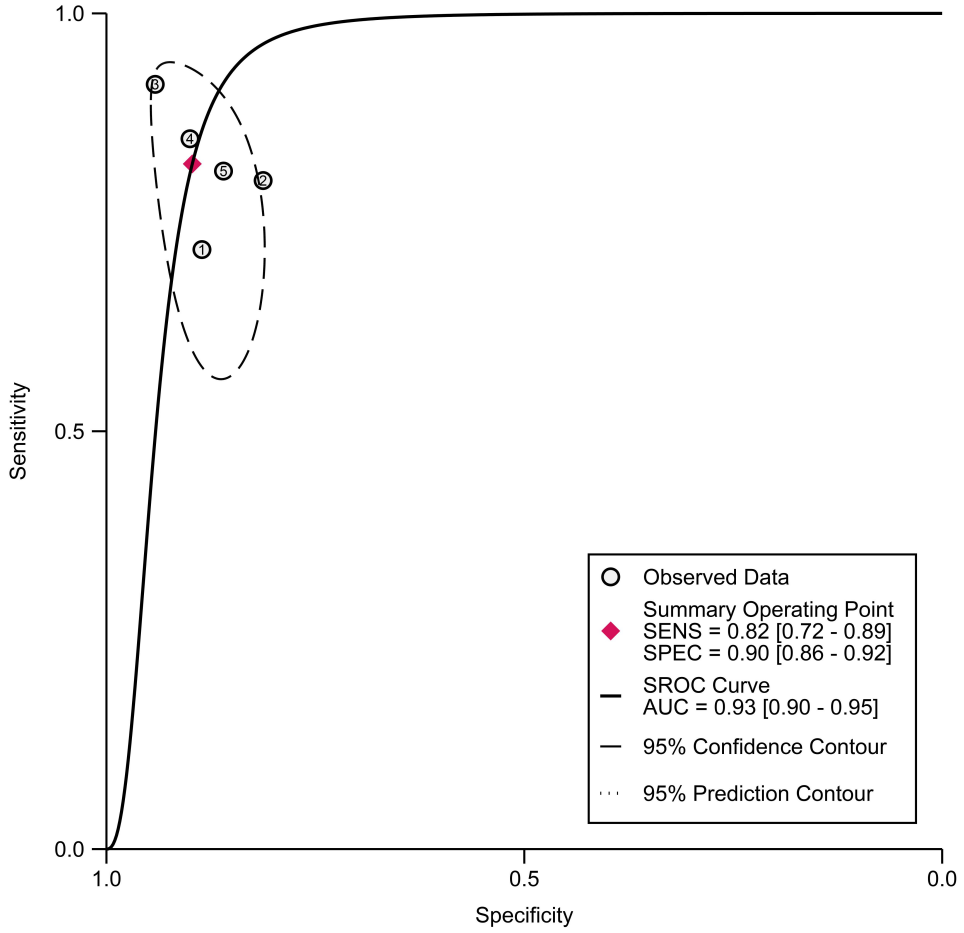
Supplementary Fig. 6. Forest plot of the diagnostic accuracy of the standalone dCDT for MCI in studies employing logistic regression. dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment.



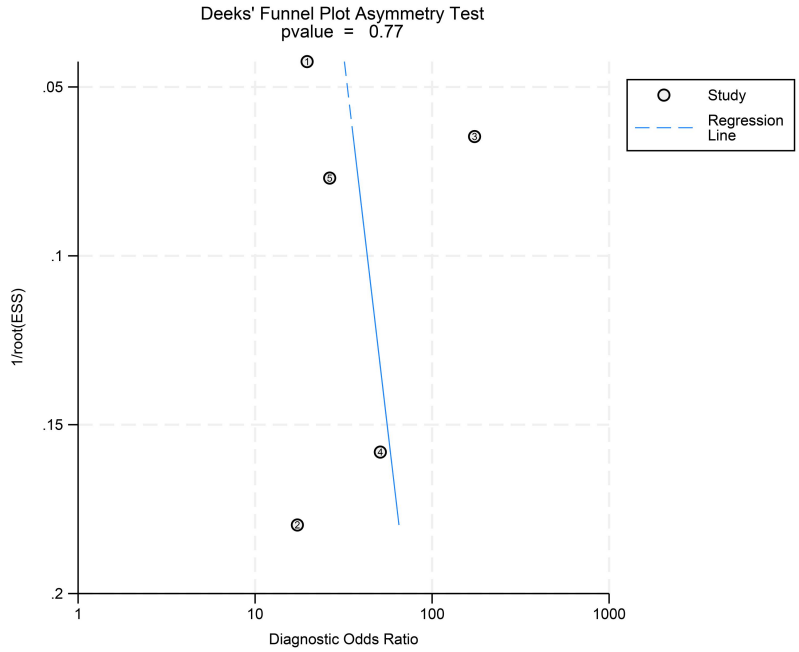
Supplementary Figure 7. Forest plot of the diagnostic accuracy of the standalone dCDT for MCI by study region. Forest plot showing the diagnostic accuracy of the dCDT for MCI, stratified by study region: (a) studies conducted in China; (b) studies conducted in Western countries. dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment.



Supplementary Fig. 8. Forest plot of the diagnostic accuracy of the standalone dCDT for MCI by risk of bias. Forest plot showing the diagnostic accuracy of the dCDT for MCI, stratified by study risk of bias: (a) studies rated as relatively high RoB; (b) studies rated as relatively low RoB. dCDT, Digital Clock Drawing Test; MCI, Mild Cognitive Impairment; RoB, Risk of Bias.



Supplementary Fig. 9. SROC curve of the dCDT for AD diagnosis. The SROC curve illustrates the diagnostic performance of the dCDT in diagnosing AD. The AUC reflects the overall accuracy, with a higher AUC indicating better diagnostic ability. SROC, summary receiver operating characteristic curve; dCDT, Digital Clock Drawing Test; AD, Alzheimer's disease.



Supplementary Fig. 10. Deeks' funnel plot of publication bias in dCDT for AD diagnosis. The Deeks' funnel plot assesses the potential publication bias in studies evaluating the diagnostic accuracy of the dCDT for AD. The plot appears symmetrical, suggesting a low likelihood of publication bias, as indicated by a p-value of 0.77. dCDT, Digital Clock Drawing Test; AD, Alzheimer's disease.