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A Meta-Analytic Study of Computerized Dynamic Assessment in English Language Learning: trends, effectiveness, and implications

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Abstract

This meta-analysis provides a comprehensive evaluation of research studies on computerized dynamic assessment (C-DA) in English language teaching and learning, addressing the need for a systematic overview in light of recent technological advancements. A systematic search across three databases (ERIC, Web of Science, and Scopus) initially identified 2807 articles, with 22 C-DA studies meeting the inclusion criteria after screening. Findings reveal that C-DA significantly enhances language learning outcomes, particularly in reading and listening and writing skills, with large effect sizes reported across multiple studies. Interventionist approaches and quasi-experimental designs were most commonly used, reinforcing the strong impact of mediation on bridging learners' actual and potential performance. While C-DA demonstrated substantial improvements in skill-based outcomes, its effects on affective factors like anxiety and intrinsic motivation were more modest. These findings highlight C-DA's potential as a transformative tool in language assessment and instruction, particularly when mediation is tailored to learners' needs. However, integrating C-DA with complementary strategies may be necessary to address psychological and motivational factors.

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Introduction

Dynamic Assessment (DA) represents a significant departure from traditional assessment paradigms, viewing assessment not as a static measure of current ability, but rather as an integrated and dynamic process interwoven with instruction (Barabadi et al., 2018). Instead of solely focusing on what learners *can* do independently, DA emphasizes their *potential* for development with appropriate support. This approach recognizes that learning is a process of growth, and assessment should be a tool to facilitate that growth by understanding the learner's Zone of Proximal Development (ZPD) (Vygotsky, 1978). Central to DA is the interactive nature of the assessment process, where a mediator (often a teacher) engages learners in a dialogue, providing graduated assistance and feedback to guide them towards mastery (Lantolf & Poehner, 2004). This interaction allows teachers to tailor their instruction to the specific needs of learners, providing the most effective support for their development (Robinowitz, 2010). By actively participating in the assessment process, learners become more aware of their learning strategies and gain insights into how to approach new tasks, ultimately fostering greater autonomy and self-regulation. The collaborative relationship between mediator and learner in DA fosters a supportive learning environment, unlocking learners' potential and empowering them to achieve more than they could independently (Barabadi et al., 2018).

The advent of C-DA has introduced a new dimension to this approach. C-DA leverages technology to deliver standardized, pre-planned, and automated mediations, often through computer-assisted platforms. This offers several advantages. First, C-DA allows for the immediate and consistent delivery of hints and feedback, ensuring that learners receive support at the optimal moment. Second, it provides flexibility for learners, enabling them to engage with the assessment at their own pace and convenience. Finally, C-DA facilitates efficient record-keeping by automatically generating individual learner profiles and performance data after each task (Ebadi & Saeedian, 2015). This detailed tracking allows for more precise monitoring of learner progress and can inform future instruction.

While the potential of C-DA is significant, research in this area requires further investigation, particularly concerning the systematic evaluation of learning outcomes and the influence of moderating variables. Current research often lacks the scope and rigor needed to draw definitive conclusions about the effectiveness of C-DA interventions for language learning. Therefore, this meta-analysis aims to address this gap by systematically synthesizing and evaluating existing experimental and quasi-experimental research studies on C-DA. Specifically, this meta-analysis will examine trends in implementation, analyze the reported effects of C-DA interventions, and explore potential moderating variables that may influence learning outcomes. The analysis will encompass studies published in three prominent academic databases between 2018 and 2024, providing a comprehensive overview of the current state of research in this emerging field

1. Literature review

1.1. Computerized Dynamic assessment in ELT

C-DA refers to the integration of digital technologies into the framework of DA to evaluate and enhance learners' abilities within an educational context. Rooted in Vygotsky's (1978)

sociocultural theory, particularly the concept of the Zone of Proximal Development (ZPD), C-DA combines assessment and instruction by providing learners with tailored feedback and scaffolding during the assessment process. Unlike traditional static assessments that measure learners' independent performance, C-DA focuses on their potential for learning by evaluating how they respond to mediated support delivered through computer-based platforms (Poehner & Lantolf, 2013). C-DA is characterized by several key features that distinguish it from conventional assessment methods: Interactive Feedback (Teo, 2012), Scaffolding (Poehner, 2008), Individualization (Lantolf & Poehner, 2011), Integration of Technology: C-DA leverages computer-based platforms, such as software applications or online systems, to deliver assessments and mediate learning interactions (Shabani, 2016), and Formative Focus (Poehner & Lantolf, 2005).

1.2. Theoretical Underpinnings Related to Technology Use in DA

The theoretical foundation of C-DA is deeply rooted in Vygotsky's (1978) sociocultural theory, which emphasizes the role of social interaction and mediation in cognitive development. The concept of the ZPD, which refers to the gap between a learner's current abilities and their potential abilities with guidance, is central to C-DA. Technology serves as a mediator in this process, enabling the delivery of scaffolded support in a structured and adaptive manner (Lantolf & Poehner, 2011). The integration of technology into DA aligns with the principles of mediation and internalization, as digital tools facilitate the interaction between the learner and the task, allowing for the gradual transfer of responsibility from the system to the learner (Poehner & Lantolf, 2013). Furthermore, the use of technology in C-DA supports situated learning, where learners engage in authentic, contextually relevant tasks that mirror real-world language use (Shabani, 2016).

1.3. Empirical Evidence on the Effectiveness of C-DA in ELT

Research on the effectiveness of C-DA across various language skills highlights its potential to enhance learning outcomes, though with some limitations. Many researchers, studied the two receptive skills of listening and reading (e.g., Ebadi & Saeedian, 2016; Delvand, & Heidar 2020; Mehri Kamrood, et el., 2018; Pishghadam, et al., 2011; Poehner & Lantolf, 2013; Poehner et al., 2015, Teo, 2012; Yang & Qian, 2017). In reading, C-DA has been shown to improve comprehension and critical thinking by providing scaffolded support, enabling learners to decode complex texts and infer meaning more effectively (Poehner & Lantolf, 2013; Shabani, 2016). Estaji and Saeedian (2020) also investigated the applicability of computer-mediated Dynamic Assessment (DA) on reading comprehension ability of the learners. In this mixed-methods study, it is resulted that the mediations offered by the computer is effective while a teacher is present as well. However, the research suggests that over-reliance on technology may hinder the development of independent reading strategies (Teo, 2012). In listening, C-DA tools offering real-time feedback and repetition options have improved learners' ability to process spoken language, particularly in identifying key information and recognizing phonological patterns (Lantolf & Poehner, 2011). Yet, its effectiveness in fostering higher-order skills like inferencing and critical listening remains limited (Poehner, 2008). In another study, Ebadi et al (2023) explored the learner's perspectives on an online DA software for listening comprehension. The results indicated that for some, the C-DA software was novel,

interesting, effective, supportive while, a few others assumed it was time-consuming and stressful. For writing, C-DA provides immediate, adaptive feedback on grammar, coherence, and organization, helping learners revise and improve their texts in real time (Shabani, 2016; Poehner & Lantolf, 2013). However, it may not fully address the creative and expressive aspects of writing, which often require human mediation (Teo, 2012). Babamoradi et al (2018) studied learners' attitudes in developing their writing skill through C-DA. The students wrote their attitudes in form of diaries and all the learners agreed on the positive effects of implementation of C-DA in their writing tasks. In speaking, C-DA has shown promise in improving fluency and accuracy through immediate feedback on pronunciation and grammar (Lantolf & Poehner, 2011; Poehner, 2008), but it may fall short in addressing communicative competence, such as pragmatics and cultural context (Shabani, 2016). Heshmat et al (2021) attempted to check the effects of two models of dynamic assessment (group dynamic assessment (G-DA) and C-DA) on EFL learners' speaking complexity, accuracy, and fluency. The results showed that C-DA and G-DA increased speaking CAF than the conventional non-DA instruction with C-DA moreover, it is proposed that implementing DA, especially C-DA by the teachers, improves the speaking CAF of the L2 learners. Finally, C-DA has been particularly effective in vocabulary and grammar acquisition, offering contextualized feedback that enhances retention and accuracy (Poehner & Lantolf, 2013; Shabani, 2016). However, its ability to address the complexities of authentic communication remains limited (Teo, 2012). Overall, while C-DA demonstrates significant potential in improving technical language skills, its integration with complementary strategies may be necessary to address higher-order and affective aspects of language learning.

An overview of the research in C-DA reveals that while there have been conducted some meta-analysis studies on the DA (e.g. Rezaee et al., 2019), there appears to be no meta-analysis studies on C-DA. Despite the growing body of research on C-DA in English Language Teaching (ELT), several key gaps and limitations remain in the existing literature. First, while numerous studies have explored the effectiveness of C-DA across various language skills (e.g., reading, listening, writing, speaking, vocabulary, and grammar), the findings are often fragmented and inconsistent, making it difficult to draw definitive conclusions about its overall impact (Poehner & Lantolf, 2013; Shabani, 2016). Additionally, many studies suffer from small sample sizes, limited geographical scope, or a lack of longitudinal data, which restricts the generalizability of their findings (Teo, 2012). Furthermore, there is a notable absence of quantitative synthesis in the field, as most reviews have been narrative or qualitative, leaving a gap in understanding the magnitude of C-DA's effects across different contexts and learner populations (Lantolf & Poehner, 2011). Finally, while C-DA has been praised for its potential to provide individualized feedback, there is limited research on its long-term effectiveness in fostering autonomous learning and transferable skills (Poehner, 2008).

This meta-analysis seeks to address these gaps by systematically synthesizing quantitative evidence to provide a clearer understanding of C-DA's effectiveness across different contexts and learner populations. By doing so, it aims to inform evidence-based practices, guide future research, and contribute to the growing body of knowledge on technology-enhanced language assessment. This meta-analysis aims to address these gaps by systematically synthesizing quantitative evidence from existing studies to provide a clearer picture of C-DA's effectiveness

in ELT. Specifically, it will focus the following on key characteristics: participant number, level, and age; publication year; interventionist vs. interactionist approaches; language skills assessed; group vs. individual C-DA; materials; and research design and effect sizes.

2. Method

2.1. Protocol and Registration

This meta-analysis is carried out in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) by Page et al. (2021) (see Figure 1).

2.2. Systematic review process

The systematic review process was conducted in a structured and methodical manner to ensure the selection of relevant and high-quality studies. The process was divided into four main stages: identification, screening, eligibility assessment, and inclusion. Each stage was carefully executed to minimize bias and ensure the reliability of the findings.

2.2.1. Identification

The initial phase of the systematic review involved the identification of potential studies through comprehensive searches across three databases (i.e., Education Resources Information Center (ERIC), Web of science and Scopus). These databases were selected, as they encompass high-quality journals related to educational technology. Search terms were applied to abstracts, titles and keywords, and filtered for journal articles published from 2018 to 2024. A total of 2807 records were identified from three academic databases. After the removal of 2659 duplicate and irrelevant records prior to screening, 148 potentially relevant studies were retained for further evaluation.

The search terms used in the systematic review were at first some general and main key words. Computerized dynamic assessment was the core of searching and the search was from 2018 to 2024. However, as shown in Table 1, based on reviewing abstracts of returned articles search terms were refined in the following searching (adding The AND, OR and NOT operands were also included to reduce the number of articles in some areas). The first bracketed section lists various terms related to C-DA. The second bracketed section lists terms related to language learning. The third bracketed section lists terms related to specific language skills, including reading, writing, listening, speaking, pronunciation, vocabulary, and grammar.

2.2.2. Screening

In the screening phase, the *148 studies* identified in the previous stage were subjected to an abstract review to determine their relevance to the research question. During this process, *103 records* were excluded as they did not meet the preliminary criteria for inclusion. The remaining *45 studies* were then assessed in full text to evaluate their suitability for inclusion in the review. At this stage, 23 full-text articles were excluded due to their lack of alignment with the research objectives or failure to meet the inclusion criteria.

Table 1. *Search Terms Used in the Systematic Review*

C-DA	AND	Language learning	AND	Skills
Computerized dynamic assessment		English learning		Reading
C-DA		English language learning		Reading comprehension
Dynamic assessment		English as the second language		Reading skill
Adaptive assessment		English as the foreign language		Writing
Adaptive learning		Second language learning		Writing skill
Scaffolding assessment		Foreign language learning		Listening
Computerized language learning		ESL		Listening comprehension
Technology-enhanced dynamic assessment		EFL		Listening skill
Web-based dynamic assessment		TESOL		Speaking
		TEFL		Speaking skill
				Oral communication
				Pronunciation
				Accent
				Vocabulary
				Lexical development
				Grammar

2.2.3. Eligibility

Following the removal of duplicates and titles/abstracts that were irrelevant to the research topic, 148 studies written in English were retained. These studies were thoroughly examined and evaluated against predefined inclusion and exclusion criteria. The inclusion criteria for the studies were as follows:

1. Publication Year: Studies published between 2018 and 2024.

2. Focus: Only studies focusing on dynamic assessment through computers were included. Studies involving applications in dynamic assessment, dissertations, and conference papers were excluded.

3. Publication Type: Studies had to be published in peer-reviewed journals.

4. Research Design: Studies were required to be both quantitative (experimental or quasi-experimental in nature) and qualitative.

To further refine the search and ensure the relevance of the selected studies to the research question, additional criteria were applied. Eligible studies were required to: (1) pertain to computerized dynamic assessment, (2) address English language learning through computer-based methods, (3) involve ESL or EFL students/language learners, (4) focus on mainstream education students engaged in English language learning via computers, and (5) provide full-text access and sufficient data for meta-analysis. Studies were deemed ineligible and excluded if they: (1) were written in a language other than English, (2) lacked sufficient data or full-text

availability, (3) emphasized general language learning through computers rather than the specific use of computers in dynamic assessment, or (4) exhibited inadequate research design or failed to employ appropriate research methodologies. After applying these criteria, **22** studies were deemed eligible for inclusion in the systematic review.

2.2.4. Inclusion

The final phase of the systematic review process involved the inclusion of the 22 studies that met all eligibility criteria (Table 2). These studies were thoroughly analyzed and synthesized to address the research question.

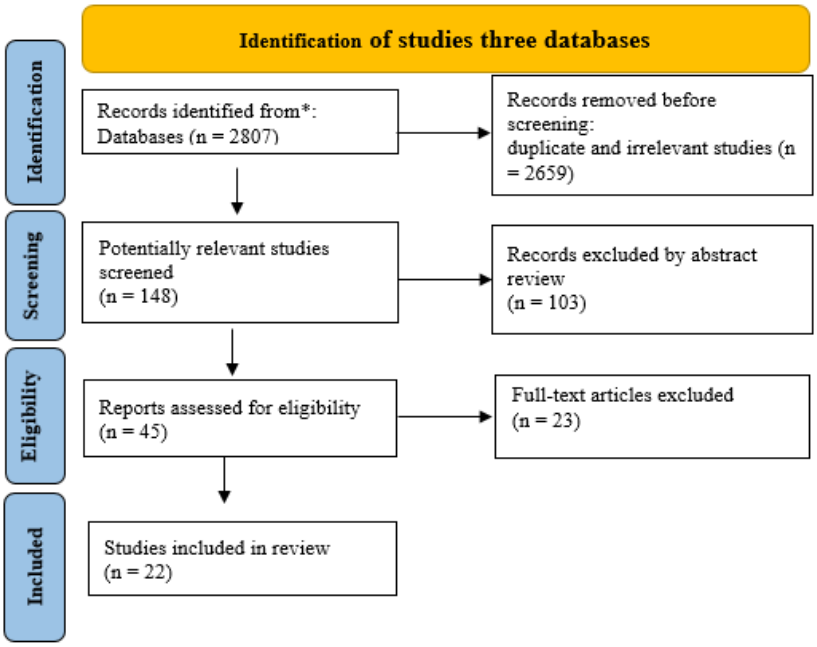

Figure 1. *Flow Chart of the Literature Search Process.*

Table 2. *Studies Included in the Final Analysis*

Code	Author(s)	Sample Size	Age	Proficiency Level	Skill(s)	Duration	Group vs. Individual DA	Instruments	Interactionist/ Interventionist DA	Design	Results	DOI
A1	Bakhoda & Shabani (2018)	183	14-18	Intermediate	Reading comprehension	Four days	Individual	- Nelson English proficiency test - 15 reading comprehension passages - C-DA software	Interactionist	Quasi-experimental	- Learners demonstrated a preference for visual mediations, followed by textual and audio mediations. - A significant difference between learners' actual and mediated scores, indicating ZPD growth. - Learners with lower actual scores benefited more from mediations.	
A2	Barabadi et al. (2018)	91	Mean age: 16	Not mentioned	Listening comprehension	Not specified	Individual	Computerized Dynamic Listening Test (CDLT)	Both	Quasi-experimental	- Test takers significantly improved their scores after receiving mediation.	

											- The test demonstrated validity and reliability. - LPS differentiated learners with the same actual scores, indicating varying responsiveness to mediation.	
A3	Babamoradi et al (2018)	22	Mean age: 25	Upper-intermediate	Writing	Not specified	Individual	- Researchers' developed Software - TOEFL ITP tests - Diary writing by students - The open-ended questions	Interventionist	Diary writing	All the learners had positive attitudes toward the implementation of C-DA in teaching writing.	10.12973/iji.2018.11346a
A4	Mehri Kamrood et al. (2018)	43	21-37	Not mentioned.	Listening comprehension	Not specified. (one-time testing session)	Individual	- Online C-DA software (CDTELP) with listening items adapted from TOEFL iBT practice tests.	Interventionist	Quasi-Experimental	- Learners generally sustained their performance on the TR tasks, indicating some transfer of learning. - Analysis of TR scores by construct and individual revealed instances of regression, sustenance, and progress. - LPS emerged as a potential indicator of future learning, supporting its predictive validity.	Not provided
A5	Mehri Kamrood et al. (2019)	54	21-37	Upper intermediate and advanced levels	Listening comprehension	Not specified (in one session)	Individual	- Online C-DA software for listening comprehension.	Interventionist	Quasi-experimental	- Significant difference between learners' actual and mediated scores, indicating the effectiveness of mediation. - LPS differentiated among learners with the same actual scores, revealing varying levels of learning potential.	10.1080/09588221.2019.1645181
A6	Ebadi et al (2018)	72	16-24	Intermediate	Vocabulary	7 weeks	G-DA	- C-DA software - transfer tasks • Post-tests of target words	Interventionist	Quasi-experimental	- Vocabulary gains in the C-DA group were significantly higher than those in the SA group. - Noticing unfamiliar words and using a DA approach enhances vocabulary gains from lexical inferencing.	10.1080/09588221.2018.1451344
A7	Ebadi & Saeedian (2019)	32	26-33	B1, B2, and C1	Reading comprehension	Not specified.	Individual	- CDRT - DIALANG	Interventionist	Experimental	- Learners with the same pretest scores showed different DA posttest scores and LPSs.	10.22132/tel.2019.92190

											- C-DA helped identify and support at-risk students.	
A8	Yang & Qian (2019)	138	19	Advanced	Reading comprehension	4 weeks of EPs	G-DA	- TOEFL reading comprehension - C-DA - Multiple-choice questions	Interventionist	Quasi-experimental	- The experimental C-DA group showed significant improvement in reading comprehension. - C-DA was more effective than conventional teaching and assessment methods in promoting reading comprehension.	
A9	Estaji & Saeedian (2020)	20	21-29	C1 and C2	Reading comprehension	Three 90-minutes	Individual	- DIALANG (placement test), CDRAT1 and CDRAT2 researcher-made software programs	Both	Mixed-methods	- HCM group outperformed the other two groups. - No significant difference between HO and CO groups. - C-DA significantly enhanced reading comprehension. - Effectiveness of different mediation types.	
A10	Estaji & Safari (2020)	51	19-27	Intermediate	Listening comprehension and working memory span	16 sessions over 1.5 months	G-DA	- Oxford Placement Test (OPT) for homogeneity. - TOEFL iBT listening test as a pre-test and post-test.	Interventionist	Experimental	- C-DA significantly improved the listening comprehension of the experimental group compared to the control group. - C-DA did not significantly affect the working memory span of the learners. - There was no significant interactional effect of C-DA and working memory on listening comprehension.	
A11	Hidri & Fekri Pileh Roud (2020)	185	20-36	Upper-intermediate	Reading comprehension	Not specified.	Individual	- TOEFL iBT Reading passages - Computer software	Interventionist	Quasi-experimental	- C-DA improved learners' performance - A significant relationship between actual and mediated performance in different question types.	
A12	Delvand & Heidar (2020)	80	Not mentioned	Intermediate	Listening comprehension		G-DA	- CoolSpeech software - listening tasks	Not mentioned	Quasi-experimental	- The participants in high self-efficacious experimental group achieved significantly better scores than the other groups.	

											- Significant effect on the listening comprehension ability of EFL learners with high self-efficacy.	
A13	Kao & Kuo (2021)	172	13-15	Beginner (A1-B1)	Listening comprehension	Not specified	Individual	- iSpring Quiz Maker (C-DA program) - TOEIC Bridge test items - C-DA perception questionnaire	Both	Mixed-methods	The mediation provided via the CDA program was most effective.	10.1080/10494820.2021.1876738
A14	Pileh Roud & Hidri (2021)	185	20-36	Upper-intermediate	Listening comprehension	70 minutes	Individual	• IELTS or TOEFL • Adapted TOEFL iBT listening test • C-DA software	Interventionist	Experimental	- C-DA revealed the potential for learning in different question types, with function items showing the highest learning potential. - There were significant differences in the number of hints used across different ability levels for some question types.	10.1007/s10639-021-10688-x
A15	Heshmat Ghahderijani et al (2021)	90	18-21	Upper-intermediate	Speaking	16 sessions	G-DA	- OQPT - PET speaking test - Speaking CAF rating scale	Both	Experimental	- Both C-DA and G-DA significantly improved speaking CAF compared to the non-DA group. - C-DA was significantly more effective than G-DA in improving speaking CAF.	10.1186/s40468-021-00144-3
A16	Ghenaat et al. (2022)	80	18-32	Intermediate	Listening comprehension	15 sessions of 45 min each	Both	- PET - TOEFL Junior Standard Test (listening section) - Animation-related listening comprehension quizzes - C-DA software - DIALANG.	Both	Quasi-experimental	- All three types of DA (I-DA, G-DA, C-DA) had a significant positive effect on learners' listening comprehension compared to the control group. - G-DA had the most substantial positive impact on listening comprehension, followed by C-DA and then I-DA.	Not provided
A17	Ebadi et al. (2023)	94	Not mentioned	B2	Listening comprehension	1 month	Individual	- Online C-DA software (www.lingeli.com) targeting inferential listening skills. - Semi-structured interviews (in Persian)	Interventionist	- Qualitative content analysis	- Positive perceptions	10.1186/s40468-23-00221-0
A18	Sherkuziyeva et al. (2023)	64	16-23	Intermediate	Oral proficiency and writing performance and test anxiety	Not specified	Individual	- PET - The Science Anxiety Scale (SAS) - Writing Scale - Oral Proficiency Scale	Interventionist	Experimental	- The experimental group outdid the control group on the oral proficiency, writing performance, and test anxiety post-tests.	10.1186/s40468-023-00227-1

											- Iranian EFL learners were able to improve both their written and oral skills while experiencing less test anxiety thanks to C-DA.	
A19	Estrada-Araoz et al. (2023)	87	Mean age: 19	Intermediate	Reading motivation, reading self-concept, autonomy, and self-regulation	Not specified	Individual	1.Prelimi- nary English Test (PET) 2. Self-Regulatory Strategies Scale (SRSS) 3. Reading Self-Concept Scale 4. Reading motivation scale 5. Learner autonomy questionnaire	Interventionist	Experimental	- The C-DA group outperformed the CFA group in reading motivation, reading self-concept, autonomy, and self-regulation. - C-DA helped EFL students improve their reading motivation, reading self-concept, autonomy, and self-regulation.	10.1186/s40468-023-00273-1
A20	Abdel-Al Ibrahim et al. (2023)	91	18-29	Intermediate	Listening comprehension	5 sessions	G-DA and C-DA	- OQPT - Researcher-made listening comprehension test - Ahvaz Perfectionism Scale (APS) - State-Trait Anxiety Inventory (STAI) - Academic Self-Regulation Questionnaire (SRQ-A)	Interventionist	Quasi-experimental	- Both G-DA and C-DA significantly improved listening comprehension compared to the control group, with no significant difference between G-DA and C-DA. - Both G-DA and C-DA increased learners' perfectionism, reduced foreign language anxiety, and enhanced intrinsic motivation.	10.1186/s40468-023-00245-5
A21	Ebadi & Goodarzi (2023)	24	19-28	Advanced	Reading comprehension	Not specified	Individual	- CDRT - Learning Style Survey - Interview	Interventionist	Mixed-method	- The results of LPS formula categorized six of the participants as non-gainers of CDRT - Some common tendencies regarding field-independency, impulsivity/reflectivity, and metaphoric/literal style preferences supported in learners' interviews.	10.1080/02702711.2022.2141393
A22	Kargar Behbahani & Karimpour (2024)	52	Mean: 20	Intermediate	Grammar	Not specified	G-DA	- OQPT - UGJT - TGJT	Interventionist	Quasi-experimental	C-DA significantly enhances both explicit and implicit language knowledge, challenging the conventional separation between the two.	10.1080/09588221.2024.2315504

Note: *CAF = Complexity, Accuracy, And Fluency; C-DA = Computerized Dynamic Assessment; CDRT = Computerized Dynamic Reading Comprehension Test; CFA = Computerized Formative Assessment; CO = Computer-only; DA = Dynamic Assessment; EP = Enrichment Programs; G-DA = Group Dynamic Assessment; HCM = Human-computer Mixture; HO = Human-only; I-DA = Interactionist Dynamic Assessment; LPS = Learning Potential Scores; OQPT = Oxford Quick Placement Test; SA = Static Assessment; UGJT = Untimed Grammaticality Judgment Test ; TGJT = Timed Grammaticality Judgment Test*

3. Findings

The selected papers in the systematic review were published between 2018 and 2024 in a range of peer-reviewed journals across multiple disciplines, including language education, cognitive assessment, and digital learning environments. The majority of studies appeared in journals related to language testing, applied linguistics, and computer-assisted language learning, reflecting the interdisciplinary nature of research on C-DA. Among the most frequently represented journals were Language Testing in Asia, Computer Assisted Language Learning, and the International Journal of Instruction. These journals specialize in language assessment, technology-enhanced learning, and instructional methodologies, making them key outlets for research on C-DA.

3.1. Categorizing C-DA Studies for their purposes

The aims of the various C-DA studies, can be broadly categorized into several key areas: (1) evaluating the effectiveness of C-DA on language skills (A4, A5, A7, A9, A11, A12, A14, A22), (2) comparing C-DA with other assessment or teaching methods (A8, A15, A16, A19), (3) exploring learners' attitudes and preferences (A1, A3, A17), (4) diagnosing learning difficulties and needs (A13, A21), and (5) investigating the cognitive and affective impacts of C-DA (A10, A18, A20).

3.2. Participants' Features: Sample Size, Age and Proficiency Level

The sample sizes across the included studies, as shown in Table 3, ranged from small-scale studies with 20 participants to larger studies involving up to 185 learners. The distribution of sample sizes shows that approximately 36.4% of the studies had between 51 and 100 participants (e.g., A17, A18, A99). Smaller studies with fewer than 50 participants accounted for about 27.3% of the total, often involving exploratory or pilot studies (e.g., A7, A9). Larger studies with over 100 participants made up another 36.4%, typically aiming for broader generalizations and subgroup analyses (A8, A11, A13, A14).

Regarding age distribution, the age of participants in the included studies ranged from 13 to 37 years, with the majority (54.5%) focusing on young adults aged 19–29. This age group represents university-level EFL learners, who are frequently the target population for C-DA research (e.g., A6). Studies involving adolescents aged 13–18 accounted for approximately 18.2%, often conducted in secondary school settings (e.g., A2, A13). A smaller percentage of studies (27.3%) included participants aged 30 and above, typically in professional or continuing education contexts.

The proficiency levels of participants in the included studies ranged from beginner to advanced, with the majority (45.5%) focusing on intermediate-level learners. This aligns with the common use of C-DA to support learners who have foundational language skills but require further development to achieve higher proficiency (e.g., A8, A13). Upper-intermediate learners

were the focus of about 22.7% of studies, often in contexts where C-DA was used to refine specific skills, such as reading comprehension or listening (e.g., A9, A11). Advanced learners (C2 level) were represented in 13.6% of the studies, usually in skill-specific assessments (e. A9). Beginner-level learners were included in 13.6% of the studies, typically in secondary school contexts (e.g., A2, A13). A small proportion of studies (4.6%) examined mixed-proficiency groups, making it difficult to draw precise conclusions about the impact of C-DA across all levels. The predominance of intermediate learners suggests that C-DA is particularly effective for this group, but further research is needed to explore its applicability across all proficiency levels.

Table 3. *Participants' Features: Sample Size, Age and Proficiency Level*

	Factor	Number of Studies	Percentage (%)
Sample Size	Sample Size ≤ 50	6	27.3%
	Sample Size 51–100	8	36.4%
	Sample Size > 100	8	36.4%
Age	Age ≤ 18	4	18.2%
	Age 19–29	12	54.5%
	Age ≥ 30	6	27.3%
Proficiency	Beginner (A1–B1)	3	13.6%
	Intermediate (B2)	10	45.5%
	Upper-Intermediate (C1)	5	22.7%
	Advanced (C2)	3	13.6%
	Mixed Levels	1	4.6%

3.3. Skill(s)

The key factors of analysis in the present study were Skill(s), Group vs. Individual DA, instruments employed, interactionist vs. interventionist and design (see Table 4). In respect of the language skills focused in the selected studies, listening comprehension was the most frequently assessed skill, accounting for 45.5% of the studies, often using C-DA to diagnose and enhance learners' ability to process spoken language (A2, A4, A5, A10, A12, A13, A14, A16, A17, A20). Reading comprehension followed, comprising 31.8% of the studies, with a focus on C-DA's role in supporting reading strategies and comprehension skills (A1, A7, A8, A9, A11, A19, A21). Speaking (A15, A18) and writing (A3, A18) were each investigated in 9.1% of the studies, respectively, with C-DA providing feedback on coherence, fluency, and accuracy. Vocabulary and grammar received the least attention, accounting for only 4.5%, indicating a potential area for future research (A6).

3.4. Group/Individual DA

The studies in this meta-analysis employed both individual and group-based C-DA approaches, with individual C-DA being the dominant format, appearing in 72.7% of the studies (e.g., A1, A2, A3, A5, A7). This preference for individual C-DA reflects its effectiveness in providing personalized feedback and scaffolding, which allows for a more precise diagnosis of learners' abilities and potential. Group-based C-DA, used in 27.3% of the studies, was typically implemented in classroom settings to facilitate collaborative learning and peer interaction (e.g., A8, A10, A12). The prevalence of individual C-DA suggests that most researchers prioritize controlled mediation settings over collaborative environments.

3.5. Instruments

The instruments and outcome measures used in the studies varied widely, reflecting the diverse skills and assessment contexts examined. The most common instrument was web-based software, used in 59.1% of the studies (e.g., A5, A6, A7, A8, A10), highlighting the growing reliance on technology for administering C-DA. Standardized tests, such as TOEFL or IELTS-based assessments, were employed in 22.7% of the studies (e.g., A11), often as pre- and post-tests to measure learning gains. Researcher-made tests were used in 13.6% of the studies (e.g., A8), allowing for customized assessment of specific skills. Additionally, qualitative measures, such as learner perceptions and attitudes, appeared in 4.5% of the studies (e.g., A3, A17), providing insights into students' experiences with C-DA.

3.6. Interactionist/Interventionist

The studies in this meta-analysis were categorized based on their approach to C-DA, with the interventionist approach being more common, appearing in 68.18% of the studies (e.g., A3, A4, A5, A6). In contrast, interactionist C-DA, used in 4.5% of the studies, focuses on adaptive, dialogic mediation, where feedback is tailored to the learner's specific needs (A1). Both approaches have demonstrated effectiveness, though the preference for interventionist methods suggests that researchers value structured mediation over spontaneous interaction.

3.7. Design

The studies employed a variety of research designs, with quasi-experimental studies being the most frequent, making up 50% of the total (A4, A5, A6, A8, A11, A12, A16, A20, A22). Experimental designs, often conducted in controlled settings, were used in 27.2% of the studies, allowing for more precise measurement of C-DA's effects (A7, A10, A14, A15, A18). Mixed-method studies, which combine quantitative and qualitative data, accounted for 13.6%, providing a more holistic understanding of how learners interact with C-DA (e.g., A9, A13, A21).

Table 4. *Summary of Studies by Key Factors*

	Factor	**Number of Studies**	**Percentage (%)**
Skill(s)	Listening	10	45.5%
	Reading	7	31.8%
	Writing	2	9.1%
	Speaking	2	9.1%
	Vocabulary/Grammar	1	4.5%
Group/Individual DA	Individual	16	72.7%
	Group	6	27.3%
Interactionist/Interventionist	Interventionist	15	68.18
	Interactionist	1	4.55
	Both	5	22.73
	Not mentioned		4.55
Instruments	Web-based software	13	59.1%
	Standardized tests (e.g., TOEFL)	5	22.7%
	Researcher-made tests	3	13.6%
	ualitative measures	1	4.5%
Research Design	Quasi-experimental	11	50%
	Experimental	6	27.2%
	Qualitative	2	9%
	Mixed-method	3	13.6%

3.8. Key Findings of the Studies

The studies on C-DA consistently demonstrated its significant potential in enhancing various aspects of language learning (see Table 5). C-DA outperformed conventional methods, especially in improving reading comprehension and listening skills, which were the most frequently examined skills (e.g., A5, A9). The Human-Computer Mixture (HCM) approach emerged as particularly effective, with this method showing superior results compared to other C-DA formats, suggesting that a balanced integration of human and computer mediation yields the best outcomes. Additionally, C-DA was found to be more effective than G-DA in improving speaking complexity, accuracy, and fluency (CAF) (e.g., A15), emphasizing its adaptability to individual learner needs. The use of mediation, particularly for inference questions, proved highly effective, with learners showing significant growth in their Zone of Proximal Development (ZPD). Furthermore, learners with lower initial scores benefited the most from mediation, indicating C-DA's potential in supporting at-risk students. Learning Potential Scores (LPS) were crucial in differentiating learners with similar actual scores, acting as a predictive tool for future learning outcomes, as these scores highlighted varying responsiveness to the provided mediation.

However, the findings also highlight the complexities of implementing C-DA. While generally positive, learner perceptions of the technology were mixed, with some reporting challenges related to time management and the lack of social interaction (A3, A17). The effectiveness of C-DA also appeared to be influenced by factors such as question type, learner ability, and the specific type of mediation employed (A5, A9). Moreover, some studies yielded mixed results regarding the impact of C-DA on certain cognitive factors like working memory (A7), and one study questioned its ability to provide a comprehensive diagnosis of abilities within the Zone of Actual Development (ZAD) (A10). These nuances emphasize the need for careful consideration of contextual factors and further research to optimize the design and implementation of C-DA interventions.

Table 5. *Results Summary*

Key Findings	Number of Studies	Percentage (%)
Significant improvement in skills	18	81.8%
Positive learner attitudes/perceptions	3	13.6%
Limited effectiveness in higher-order skills	1	4.6%

3.9. Effect Sizes in the C-DA Studies

The effect sizes reported in the studies on C-DA provide a quantitative measure of its impact on various language learning outcomes. Large effect sizes were consistently observed in studies focusing on skill development, such as reading comprehension, listening comprehension, and writing accuracy. For instance, Estaji and Saeedian (2020) reported large effect sizes for specific reading skills, with $\eta^2 = 0.33$ for "Factual Information" and $\eta^2 = 0.32$ for "Finding Definitions," indicating that C-DA significantly enhances learners' ability to process and retain explicit information. Similarly, Mehri Kamrood et al. (2019) found a very large effect size (Cohen's $d = 2.33$) for the difference between actual and mediated scores, highlighting the transformative role of mediation in bridging the gap between learners' current and potential abilities. These large effect sizes underscore C-DA's strength in improving concrete language

skills, particularly when mediation is tailored to learners' needs. In addition to skill development, C-DA demonstrated substantial effects on psychological and affective factors, though to a lesser extent. For example, Sherkuziyeva et al. (2023) reported very large effect sizes for writing accuracy (d = 1.99), fluency (d = 2.11), complexity (d = 2.22), and oral proficiency (d = 2.53), suggesting that C-DA is highly effective in enhancing both written and spoken language performance. However, the effect sizes for affective factors like anxiety (d = 0.218) and intrinsic motivation (d = 0.228) were smaller, as seen in the study by Abdel-Al Ibrahim et al. (2023). This indicates that while C-DA excels in skill-based outcomes, its impact on learners' emotional and motivational states is more modest. These findings suggest that C-DA should be complemented with other interventions to address learners' psychological and motivational needs.

4. Discussion

The findings of this meta-analysis highlight the effectiveness of C-DA in enhancing various language skills, particularly reading and listening comprehension. The results align with previous literature emphasizing the advantages of mediation and scaffolding through technology-based assessment (Poehner & Lantolf, 2013; Shabani, 2016). The significant improvements observed in learners' performance across studies reinforce the potential of C-DA as a transformative tool in language learning.

A key finding is the predominance of interventionist approaches in C-DA, which offers standardized and automated mediation, ensuring consistency in learner feedback. This confirms previous claims that interventionist C-DA is more suitable for large-scale implementation (Estaji & Saeedian, 2020; Yang & Qian, 2019). However, studies adopting an interactionist approach also demonstrated positive effects, particularly in fostering learner autonomy and self-regulation (Estrada-Araoz et al., 2023). This suggests that a hybrid model incorporating both structured mediation and flexible, dialogic feedback may optimize language learning outcomes.

The skill-specific effects of C-DA provide further insights into its applicability. The meta-analysis confirmed that reading and listening are the most studied skills in C-DA research, likely due to the ease of designing pre-planned and automated mediation for receptive skills (Delvand & Heidar, 2020; Pishghadam et al., 2011). While writing and speaking skills showed positive gains, studies reported that C-DA alone may not fully capture the complexities of these productive skills, which often require human interaction and contextual understanding (Teo, 2012; Shabani, 2016). This indicates the necessity of complementing C-DA with human-mediated assessment to enhance expressive language abilities.

Another significant contribution of this study is the identification of factors influencing the effectiveness of C-DA, such as learner proficiency level, sample size, and assessment format. Intermediate learners benefited the most from C-DA, suggesting that they possess enough foundational knowledge to engage with mediated support while still needing scaffolding for further development (Kao & Kuo, 2021; Yang & Qian, 2019). Additionally, studies with larger sample sizes tended to yield more generalizable findings, underscoring the importance of robust research designs in future C-DA investigations.

The theoretical underpinnings of this study are rooted in Vygotsky's (1978) Sociocultural Theory and the Zone of Proximal Development (ZPD), as well as Cognitive Load Theory (Sweller, 1988). The former emphasizes the role of mediation and scaffolding in learning, which aligns with the interactive and adaptive feedback mechanisms of C-DA. The latter highlights how learners process and manage cognitive resources, which is critical in designing C-DA systems that provide optimal levels of support without overwhelming learners. These frameworks help explain why C-DA is particularly effective in fostering skill development by providing just-in-time assistance tailored to the learner's needs.

Despite the promising outcomes, some limitations of C-DA must be acknowledged. While it effectively facilitates immediate and adaptive feedback, concerns remain about its ability to nurture higher-order skills such as inferencing, critical thinking, and communicative competence (Poehner, 2008; Shabani, 2016). Moreover, technical barriers, including software limitations and learner adaptability to digital mediation, have been noted as potential challenges (Ebadi et al., 2023). Addressing these limitations through more sophisticated AI-driven adaptive systems and integrating C-DA with human-assisted assessment models may enhance its effectiveness.

The effect sizes reported in these studies collectively demonstrate that C-DA has a strong and consistent impact on language learning outcomes, particularly in areas such as reading comprehension, listening comprehension, writing accuracy, fluency, and oral proficiency. The large effect sizes (e.g., Cohen's $d > 0.8$) highlight the effectiveness of C-DA in bridging the gap between learners' actual and potential performance through targeted mediation. However, the smaller effect sizes for affective factors like anxiety and intrinsic motivation suggest that C-DA's primary strength lies in skill development rather than psychological or motivational changes. This underscores the need for complementary approaches to address learners' affective and motivational states alongside skill-based interventions.

Conclusion

In summary, this study highlights the transformative potential of C-DA in language learning, particularly in reading and listening comprehension. By integrating technology with scaffolding and mediation, C-DA offers a structured yet adaptable approach to assessment, aligning with key theoretical frameworks such as Vygotsky's Sociocultural Theory and Cognitive Load Theory. The findings suggest that while interventionist C-DA is widely effective, a hybrid approach incorporating interactionist elements may further optimize learning outcomes. However, challenges remain, particularly in the assessment of higher-order skills and the need for human mediation in productive language abilities. The success of C-DA is also influenced by factors such as proficiency levels, sample size, and the balance between automation and personalized feedback. Future research should focus on refining C-DA methodologies, exploring its long-term impact, and integrating it with emerging technologies such as artificial intelligence and virtual learning environments to enhance learner autonomy and engagement. By addressing these areas, C-DA can continue to evolve as a vital tool in modern language education.

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