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Digital Therapy Interventions for Improving Communication Skills in Children with Autism Spectrum Disorder: A Scoping Review

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Abstract. To review the research and application status of digital therapy interventions for improving communication skills in children with autism spectrum disorder (ASD) and to provide evidence-based references for clinical practice.Following the PRISMA guidelines,we searched eight electronic databases for relevant records from their inception through March 2026. The search strategy used Boolean operators with both subject headings and freetext terms,and we also checked the reference lists of eligible studies by hand. Twentyone randomized controlled trials were included. Across these studies,digital therapy interventions shared several recurring features: teaching basic skills,providing key skills training,offering gamified and immersive practice,empowering and training caregivers,using datadriven feedback to make individualized adjustments,and enabling remote collaboration with professionals. Outcome assessments focused mainly on core ASD symptoms. The trial data suggests that digital therapy may improve emotion recognition,social responsiveness,and cognitive flexibility in children with ASD,while also showing good feasibility and acceptability. Taken together,these findings indicate that digital therapeutic approaches may help reduce core symptoms and improve related functional outcomes in this population.

Keywords: Digital therapeutic intervention, Autism spectrum disorder, Children, Cognitive flexibility, Scoping review

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental condition marked by persistent difficulties in social communication and interaction,along with restricted interests and repetitive,stereotyped behaviors. According to a survey carried out in 2020,about 0.70% of Chinese children aged 6 to 12 years meet the diagnostic criteria for ASD [1]. Many of these children have difficulty with emotion recognition,social interaction,and behavioral regulation. These problems affect daily life,learning,and family functioning,and they also increase pressure on rehabilitation services. Comorbidity makes this more difficult. The rate of cooccurring attentiondeficit/hyperactivity disorder (ADHD) has been reported to range from 24.3% to 68.0% [1,

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2], and specific phobias affect roughly 30% to 64% of these children [3], which adds further challenges to intervention.

Early behavioral interventions can improve core symptoms and support adaptive abilities,but the usual service model still has major structural limits. Trained professionals are in short supply,and the cost of services can place a heavy financial burden on families. For example,annual outofpocket expenses can reach tens of thousands of Australian dollars [4]. Access is also uneven. Geographic distance and transportation problems make it difficult for many families,especially those in remote areas,to receive stable,highquality inperson care. The COVID19 pandemic exposed this problem more clearly by disrupting facetoface rehabilitation and reducing continuity of care. As a result,remote and contactfree forms of intervention became more necessary. In this setting,digital therapeutics may help by reducing limits related to time and place,lowering some costs,and offering more individualized training for children with ASD.

A range of digital interventions is already being used for this population. These include computer gamebased social skills programs [2, 5], virtual reality (VR) platforms designed for emotion and social cognition training [3, 6, 7],wearable devices that deliver social feedback [8], mobile applications grounded in applied behavior analysis [9], and digital therapeutic systems that incorporate eyetracking technology [10]. Randomized controlled trials have reported improvements in emotion recognition [11-13], social responsiveness [14, 15], and cognitive control [16] in children with ASD. Some studies also found that these approaches were feasible and acceptable [1, 10]. Still,the evidence does not yet form a clear whole. Intervention models differ substantially across studies,and the findings remain scatteblue. For that reason,a scoping review is needed to map how digital therapy interventions are being applied in children with ASD.

2. Materials and methods

2.1. Literature inclusion and exclusion criteria

Inclusion criteria were defined according to the PICOS framework: ① Population: children and adolescents (aged ≤18 years) diagnosed with ASD by clinicians or standardized diagnostic tools (DSM or ICD criteria); ② Intervention: any form of digital therapy targeting communication skills, including augmentative and alternative communication (AAC) devices, communication apps, virtual/augmented reality systems, and artificial intelligence-based personalized learning tools; ③ Comparison: no restriction (e.g., no intervention, conventional therapy, or other non-digital interventions); ④ Outcomes: primary outcome was improvement in communication skills, operationally defined based on Skinner's verbal behavior theory (mand, tact, intraverbal, listener response) and measured by direct observation, standardized scales (e.g., Vineland Adaptive Behavior Scales), or experimental task completion rates; ⑤ Study design: randomized controlled trials (RCTs), non-RCTs, pre-post single-group studies, and single-case designs.

Exclusion criteria were: ① studies including adults (>18 years) or individuals with non-ASD neurodevelopmental disorders where data could not be separated; ② interventions not primarily targeting communication; ③ incomplete full text or data; ④ reviews, commentaries, conference abstracts, dissertations, or grey literature; ⑤ non-Chinese or non-English publications.

2.2. Literature search

The search was conducted in eight databases: China National Knowledge Infrastructure, Wanfang Database, Weipu Database, Chinese Biomedical Literature Database, PubMed, Web of Science,

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Embase, and Cochrane Library, from inception to March 2026. Boolean operators combined subject headings and free-text terms. Reference lists of included studies were manually searched for additional literature. The PubMed search strategy is provided below; other databases were adapted accordingly.

2.3. Literature screening

Retrieved records were imported into EndNote for duplicate removal. Two reviewers independently screened titles, abstracts, and full texts. Disagreements were resolved through discussion or consultation with a third reviewer. The screening process followed the PRISMA flow diagram.

2.4. Data extraction and analysis

A standardized data extraction form was developed. Two reviewers independently extracted the following information: first author, year, country, sample size, age range, diagnostic criteria, functional level, digital therapy type, specific tool/software, intervention setting (clinic/school/home), duration (weeks), frequency (sessions/week), session length (minutes), control group type, communication skill type (mand, tact, etc.), measurement tools, main results (mean, standard deviation, p-value, effect size), and study methodology.

3. Results

3.1. Literature screening results

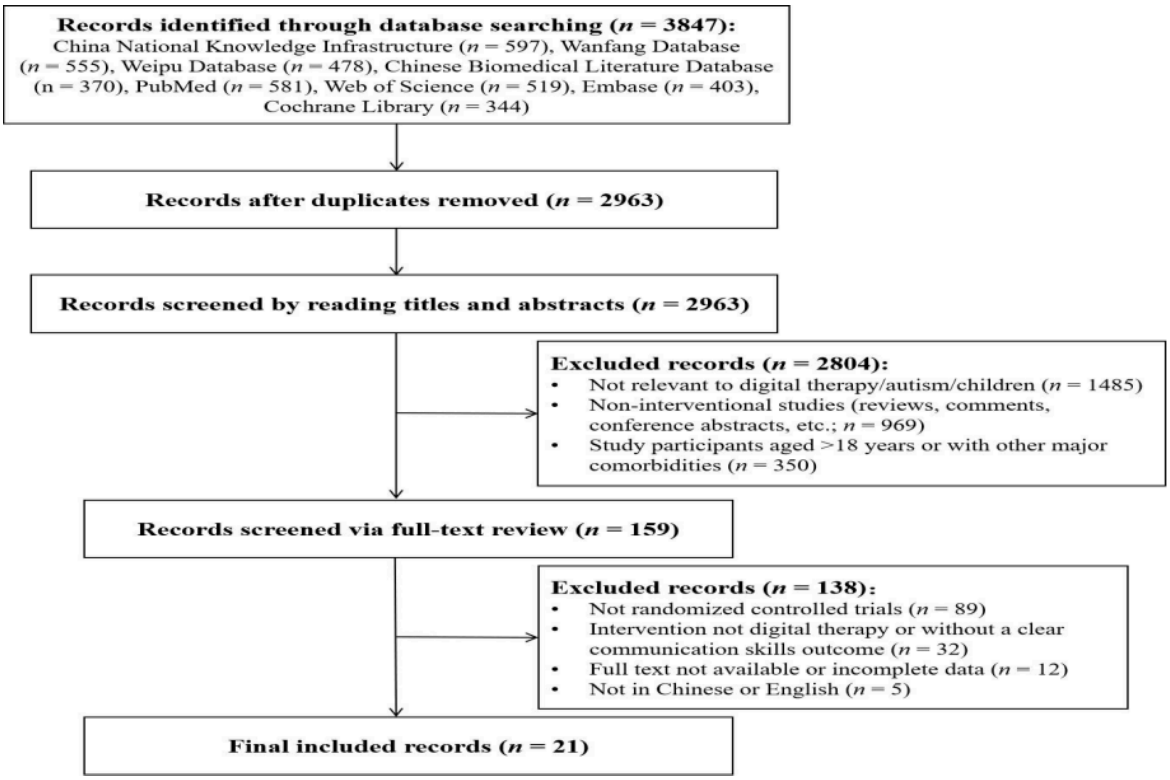

Figure 1. Literature screening flow diagram

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The initial search yielded 3,847 records. After duplicate removal and title/abstract screening, 2,963 articles remained. Following full-text assessment, 2,804 articles were excluded due to irrelevant content or insufficient scientific rigor. A total of 21 articles were finally included [1-21], all of which were randomized controlled trials (RCTs). By country: United States, 8 articles [8, 10-14, 16, 17]; Australia, 6 [2, 4, 5, 15, 18, 19]; China, 3 [1, 9, 20]; United Kingdom, 1 [3]; Italy, 1 [6]; Germany, 1 [21]; South Korea, 1 [7]. Participants were children with ASD diagnosed by professional medical institutions, aged 3 to 14 years; 20 studies focused on children, and one [21] on high-functioning adults with ASD. Basic characteristics of included studies are presented in Table 1. The literature screening flow diagram is shown in Figure 1.

Table 1. Basic characteristics of included studies (N = 21)

Included study (first author, year)	Country	Sample size (EG/CG)	Age range (years)	Diagnostic criteria	Digital therapy type/tool	Intervention setting	Intervention duration & frequency	Control group type	Content elements (code)	Main outcome measures	Main results
Chu et al. [1], 2023	China	78 (39/39)	3-6	DSM-5	VR-CBT (wearable floor projection)	Clinical	20 weeks, 2 times/week, 20 min/session	LSP intervention	B, K, G, C, R	ABC, CARS, ADHD-RS-IV, Go/No-Go	EG showed significant reductions in ABC and CARS, and improved Go/No-Go accuracy
Beaumont et al. [2], 2021	Australia	70 (35/35)	7-12	DSM-5	Computer game (Secret Agent Society)	Home + remote	10 weeks, ~20 min game + parent training per week	Cognitive skills training game	B, K, G, C, R	SSQ-P, ERSSQ, SCAS-P, ECBI	EG showed significant improvements in SSQ-P, ERSSQ, and ECBI
Maskey et al. [3], 2019	UK	32 (16/16)	8-14	DSM-IV / ICD-10	VR (Blue Room) + CBT	Clinical	4 sessions, 20 min/session	Usual care	B, K, G, C, R	Target behavior rating, SCAS-P, FSSC-R	EG showed significant improvement in target behavior (38% vs 0%)
Parsons et al. [4], 2019	Australia	59 (30/29)	2-6	DSM-5	Tablet application (TOBY app)	Home + remote	3 months, 20 min/day	Waitlist	B, K, C, R	MSEL, CSBS, POM, ToP	EG showed significant improvement in MSEL expressive language
Beaumont et al. [5], 2008	Australia	49 (26/23)	7.5-11	DSM-IV-TR	Computer game (Junior Detective)	Clinical + home	7 weeks, 2 hours once/week	Waitlist	B, K, G, C, R	SSQ-P, ERSSQ, emotion recognition, emotion management	EG showed significant improvements in SSQ-P, ERSSQ, and emotion management
Frolli et al. [6], 2022	Italy	60 (30/30)	9-10	DSM-5	VR (3D projection emotion training)	Clinical	3 months, 3 times/week	Traditional emotion training	B, K, G	Emotion recognition tasks (PE, SE, ESPE, ESSE)	EG showed shorter learning time for SE, ESPE, ESSE

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Table 1. (continued)

Lee et al. [7], 2023	South Korea	20 (10/10) *	7-12	Physician diagnosis	Metaverse (Roblox) + PEERS	Home	4 weeks, 1 time/week, 60 min/session	No intervention	B, K, G, C, R	SRS-2, K-CBCL, K-VABS-2	EG showed an 11.5-point reduction in SRS-2 total score
Voss et al. [8], 2019	USA	71 (40/31)	6-12	SCQ > 15	Wearable device (Superpower Glass)	Home	6 weeks, 4 times/week, 20 min/session	Usual ABA	B, K, G, C, R, D	VABS-II, SRS-II, NEPSY-II, EGG	EG showed significant improvement in VABS-II social subscale
Lin X. [9], 2022	China	60 (30/30)	3-6	DSM-5	Online ABA training	Home	6 months, 5 days/week, 2 sessions/day (4 units × 20 min each)	Conventional rehabilitation training	B, K, C, R	CARS, ABC, PEP-3	EG showed significant reductions in CARS and ABC, and improvements in PEP-3 communication and behavior
Sosnowski et al. [10], 2022	USA	54 (25/29)	4-14	Physician diagnosis	Digital therapy (Lookware™) + eye tracking	School / home / clinical	6 weeks, 3-5 times/week, ≥15 min/session	Control video game	B, K, G, D, R	Ekman-60, feasibility survey	EG showed significant improvement in Ekman-60 (+7.72 points)
Hopkins et al. [11], 2011	USA	49 (24/25)	6-15	DSM-IV	Computer game (FaceSay)	School	6 weeks, 2 times/week, 10-25 min/session	Drawing software (Tux Paint)	B, K, G	Emotion recognition, face recognition, SSRS, social observation	EG showed significant improvement in emotion recognition and social interaction
Rice et al. [12], 2015	USA	31 (16/15)	5-11	Educational criteria (California)	Computer game (FaceSay)	School	6 weeks (frequency not specified)	Reading software (SuccessMaker)	B, K, G	NEPSY-II (AR, ToM), SRS-2, social observation	EG showed significant improvements in AR, ToM, and SRS-2
Tanaka et al. [13], 2010	USA	79 (42/37)	6-18	ADI-R / ADOS	Computer game (Let's Face It!)	Home	20 hours (2-4 months)	Waitlist	B, K, G, D	Face recognition tasks (Parts/Whole, etc.)	EG showed significant improvement in part-based face recognition
Thomeer et al. [14], 2015	USA	43 (22/21)	7-12	ADI-R	Computer software (Mind Reading) + live rehearsal	Clinical	12 weeks, 2 times/week, 90 min/session	Waitlist	B, K, G, C, R	CAM-C, ERDS, SRS, BASC-2	EG showed significant improvements in CAM-C and ERDS

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Table 1. (continued)

Young et al. [15], 2012	Australia	25 (13/12)	4-8	DSM-IV	DVD (The Transporters)	Home	3 weeks, ≥3 short films/day	Thomas & Friends DVD	B, K, G	NEPSY-II Affect Recognition, Faces Task, SCQ	EG showed significant improvement in emotion recognition
Yerys et al. [16], 2019	USA	19 (11/8)	9-13	DSM-5	Digital therapy (Project EVO)	Home	4 weeks, 5 times/week, 25 min/session	Educational game (word generation)	B, K, G, D	TOVA, ADHD-RS-IV, BRIEF-2	EG showed medium effect size on TOVA API (g = 0.72)
Moore et al. [17], 2000	USA	14 (7/7)	3-6	Not specified	Computer software (vocabulary learning)	School	2 days, 3 new words/day	Teacher instruction	B, K	Vocabulary recall test	EG significantly outperformed teacher instruction group in vocabulary learning
Whitehouse et al. [18], 2017	Australia	80 (41/39)	2.5-5	ADOS-G	Tablet application (TOBY app)	Home + remote	6 months, ≥20 min/day	Usual community intervention	B, K, C, R	ATEC, MSEL, VABS-II, MCDI	EG showed significant improvements in MSEL visual reception and fine motor skills
Williams et al. [19], 2012	Australia	55 (28/27)	4-7	ADI-R / ADOS	DVD (The Transporters)	Home	4 weeks, 15 min/day	Thomas & Friends DVD	B, K, G	Emotion recognition, NEPSY-II ToM, Vineland	EG showed significant improvement only in anger recognition
Zeng J. [20], 2022	China	130 (65/65)	0-6	DSM-5	Micro-lecture (online)	Home	3 months (frequency not specified)	Conventional education	B, C, R	ABC, CARS, Children Mental Health Scale, ATEC	EG showed significant reductions in ABC, CARS, and ATEC
Rosenblau et al. [21], 2020	Germany	48 (25/23)	19-49	ADI-R / ADOS	Computer training (SCOTT)	Remote	3 months (frequency not specified)	Non-social computer training	B, K, R	MASC, Face Puzzle, fMRI	EG showed significant improvements in MASC and Face Puzzle

Note: EG = experimental group; CG = control group. Code for content elements: B = basic skills teaching, K = key skills training, G = gamified/immersive practice, C = caregiver empowerment and training, D = data-driven feedback and individualized adjustment, R = remote collaborative guidance from professionals.

3.2. Types and core uses of digital therapy interventions

Digital therapy interventions incorporated multiple therapeutic approaches: social skills training [2, 5-7, 11-15, 21] (10 studies), emotion recognition training [5, 10-15, 19] (8 studies), applied behavior analysis (ABA) [1, 9, 13, 18, 19] (5 studies), virtual reality exposure [3, 6, 7] (3 studies), attention/executive function training [8, 16] (2 studies), psychoeducation [4, 20] (2 studies), and cognitive behavioral therapy (CBT) [3] (1 study). Several studies [1, 2, 5, 11, 13-15] combined

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multiple approaches (e.g., social skills with emotion recognition, or ABA with parent guidance), reflecting a trend toward multicomponent interventions.

Primary intervention goals included: enhancing social communication [2, 5-7, 11-15, 21];improving emotion recognition and expression[5, 10-15, 19]; reducing problem and repetitive behaviors [1-3, 9, 13, 18, 20]; improving attention and executive function [8, 16]; alleviating comorbid anxiety and phobias [3, 4, 16, 19]; promoting language development [8, 9, 17-20]; and improving daily living skills [1, 4, 8, 9, 18, 20]. Secondary uses included parent training and empowerment [2, 4, 8-10, 20], promoting skill generalization to home and school [2, 9, 14, 15, 20], and using data feedback for individualized training [7, 8, 10, 16].

3.3. Core content and support models

Intervention content was diverse, including interactive skills training [1-3, 5-8, 10-16, 20, 21] (15-30 min/session, 3-5 sessions/week, 4-12 weeks), parent guidance and empowerment [2, 7-9, 18, 20] (online courses, manuals, live webinars, or weekly coaching), home-based practice tasks[2, 9, 14, 15, 20] (natural environment training with parent recording), data tracking and personalized feedback [7, 8, 10, 16] (automatic performance recording and algorithmic difficulty adjustment), and virtual simulation [3, 6, 7] (VR or metaverse platforms for safe exposure).

Implementation support models were classified as: ① professional-led [2, 3, 5, 7, 14, 15, 21] (therapists or researchers delivered training and supervision); ② parent-assisted [1, 4, 8, 9, 18, 20] (parents as primary implementers under remote guidance); and ③ self-guided or semi-self-guided [10, 13, 16] (children used digital tools independently). Some studies [2, 5, 14, 15] adopted a mixed model.

3.4. Technical carriers and design elements

Technical carriers included computer game software [2, 5, 11-15, 17, 19] (most common), mobile applications [1, 8-10, 18, 20], virtual reality systems [3, 6, 7] (head-mounted displays or immersive rooms), wearable devices [8] (e.g., smart glasses with real-time feedback), and remote video/telephone platforms [4, 16, 21]. Design elements emphasized adaptive mechanisms (gamification, difficulty adjustment), real-time feedback (visual/auditory cues, eye-tracking), and low technical barriers (offline access, large icons, voice guidance). Data encryption and local video storage were used in studies involving wearables or remote transmission [8, 18].

3.5. Outcome measures

Outcome measures covered multiple domains. Social skills were most frequently assessed, using the Social Responsiveness Scale (SRS-2) [7, 8], Social Skills Questionnaire (SSQ) [2, 15], or Vineland Adaptive Behavior Scales (VABS) socialization subscale [7, 8]. Emotion recognition was measured with NEPSY-II Affect Recognition [12, 19], Ekman-60 Faces [10], or Emotion Recognition and Display Survey (ERDS) [14]. Problem behaviors were assessed using the Autism Behavior Checklist (ABC) [1, 20], Childhood Autism Rating Scale (CARS) [1, 20], or Autism Treatment Evaluation Checklist (ATEC) [18]. Anxiety symptoms were measured with the Spence Children's Anxiety Scale (SCAS) [2, 4] or target behavior rating scales [3]. Executive function and attention were assessed using the Test of Variables of Attention (TOVA) [8, 16], Behavior Rating Inventory of Executive Function (BRIEF) [15], or Go/No-Go tasks [1].

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Of the 21 studies, 12 [1-3, 7, 8, 10-16] reported significant improvements in social or emotion recognition abilities, while two [18, 19] reported non-significant results for some indicators. Treatment satisfaction, system usability, and home acceptability were moderately high. Among studies reporting adherence, one [2] found that 74.2% of families completed all 10 weeks; another [10] reported high adherence levels. Attrition rates ranged from 0% to 29% [1, 3, 4, 7, 9, 10, 15, 18-20]. Technical challenges included complex device operation, unstable internet connections, and fluctuations in child attention [8, 10, 18].

4. Discussion

4.1. Core components of digital therapy interventions: a multidimensional integration

The various digital therapies covered in this review tend to cluster around six interacting parts. There is basic skills instruction, key skills training, gamified and immersive practice, caregiver empowerment with training, data-guided individualized adjustment, and remote professional collaboration. When we look across the studies we included, the heaviest emphasis fell on key skills training [2, 5-7, 11, 14, 15, 21] as well as on gamified and immersive formats [3, 6, 7, 10, 13, 16]. Researchers often turned to computer games, virtual reality, and mobile applications to help strengthen social interaction, emotion discrimination, and executive function. A smaller set of studies [1, 17, 20] put more of a focus on building foundational abilities—for instance, vocabulary learning and basic emotion recognition—and these were aimed mainly at younger children or those who needed more substantial support.Families generally responded well to the gamified elements and the real-time feedback, and they reported that these features really helped boost their children's engagement [2, 8, 10, 13]. Giving caregivers more of a role and equipping them with the right skills turned out to be a decisive factor for success [2, 9, 18, 20]; once parents had received proper training, they were in a much better position to help their children transfer what they had learned into everyday routines at home. One distinctive strength of digital delivery is data-guided individualized adjustment, which made it possible to adjust task difficulty on the fly by drawing on eye-tracking data and adaptive algorithms [8, 10, 16]. Remote collaboration with professionals [2-4, 18, 20] also helped do away with geographical barriers and offered families ongoing support. When we put all of this together, it becomes clear that these interventions have moved away from isolated skill drills and toward an integrated model that brings together technological support, family involvement, and professional guidance—which complements conventional rehabilitation services in a meaningful way.

4.2. Effectiveness and acceptability

The studies we looked at showed that digital therapies had positive effects across a range of outcomes—social skills [2, 5-7, 11, 14, 15, 21], emotion discrimination [5, 10-15, 19], problem behaviors [1-3, 9, 18, 20], and executive function [8, 16] all improved in children with ASD. At the same time, though, a couple of the studies [18, 19] didn't find reliable changes on certain indicators, and that may have been due to shorter intervention periods, smaller sample sizes, or measurement tools that weren't sensitive enough to pick up the changes. When we turned our attention to caregivers, digital therapies were linked to lower levels of parenting stress [2, 7, 20] and to better self-efficacy and family quality of life [2, 9, 10, 18, 20]. Most families found the digital tools easy to use and acceptable, and they reported being satisfied with them [2, 8, 10, 18, 20]. That said, some did mention that the content didn't always feel tailored enough to their specific needs [9, 19], and

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others ran into technical glitches or unreliable internet connections that got in the way of a smooth user experience [8, 10, 18].

4.3. Implications for future research and clinical practice

Evidence to date points to benefits of digital therapies for both children with ASD and their families. Building on these findings, two complementary priorities deserve attention. One is the development of comprehensive intervention pathways and individually tailored programs delivered through digital platforms. In regions where rehabilitation resources and professional expertise are unevenly distributed, digital tools have particular strengths in online screening, assessment, and stratification, making it possible to match content to a child's profile. A hospital–community–family support continuum that enables real-time interaction with professionals, individualized rehabilitation courses, and a blend of remote and in-person services would be a logical next step. The other priority concerns evaluation. Large-sample, multi-center RCTs with extended follow-up are needed to compare digital therapies directly with conventional face-to-face interventions. Equally important are cost-effectiveness analyses that weigh resource inputs against health outputs, so that decisions about wider dissemination rest on solid economic evidence.

4.4. Limitations

We should also be upfront about the limitations of this review. Our search strategy was fairly broad, but we only included papers published in English or Chinese, and that may have introduced some language bias. The 21 studies we ended up with varied quite a bit in terms of their interventions, the ways they measured outcomes, and the characteristics of their participants—and that kind of heterogeneity made it impossible for us to run a meta-analysis, which in turn limited how strong our synthesis could be. Most of the trials had relatively small sample sizes and short follow-up periods, so we don't really have a clear picture of whether the benefits hold up over the longer term. Another issue is that blind assessment of outcomes and intention-to-treat analyses weren't reported all that often, and that does raise some concerns about internal validity. On top of all this, the technical details of how the interventions were delivered—for instance, how well participants adhered to the digital protocols and what data security measures were in place—were rarely described in a consistent manner, which makes it harder for other researchers to replicate these interventions or for clinicians to apply them in everyday practice.

5. Conclusion

This review found that digital interventions mainly fall into six areas: foundational skills training, core skills coaching, gamified immersive practice, caregiver empowerment, data-driven individualized adaptation, and remote professional collaboration. The available evidence suggests that these approaches may improve emotion recognition, social responsiveness, and cognitive flexibility, and they have generally shown good feasibility and user acceptance.

There are still clear gaps. Current work has not yet developed strong strategies to account for differences between children, and the long-term effects remain uncertain because follow-up periods are often limited and more rigorous testing is still needed. One might expect these interventions to work in similar ways across cases, but the evidence does not fully support that.

A more practical next step would be to make better use of existing digital resources to design individualized plans suited to each child's developmental stage and functional level. Larger-sample,

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multi-center RCTs with longer follow-up periods are still needed to assess both the clinical benefits and the cost-effectiveness of these interventions. Closer collaboration between professionals and families also appears necessary if rehabilitation support for children with ASD is to become more accessible and efficient.

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