

Review Article

# A Systematic Review on the Development of High-Tech Mobile Applications in Urdu, Punjabi, and Sindhi for Children with Autism Spectrum Disorder and Social Communication Disorder

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## ABSTRACT

**Background:** Children with Autism Spectrum Disorder (ASD) and Social Communication Disorder (SCD) face persistent impairments in language acquisition, social communication, and daily functioning. High-technology mobile applications have demonstrated efficacy in supporting communication and language development in these populations; however, the overwhelming majority of validated applications are developed in English and culturally oriented toward Western contexts. No prior systematic review has examined the development or effectiveness of mobile applications specifically designed in Urdu, Punjabi, or Sindhi — the three primary regional languages of Pakistan and South Asia — for children with ASD or SCD. **Objective:** To systematically identify, characterise, and appraise the methodological quality and effectiveness of high-technology mobile applications incorporating Urdu, Punjabi, or Sindhi language support for children (aged 0–18 years) with ASD or SCD. **Methods:** A systematic review was conducted in accordance with PRISMA 2020 guidelines. Five electronic databases — PubMed/MEDLINE, IEEE Xplore, Scopus, Web of Science, and Google Scholar — were searched in January 2025 from inception to search date. Two independent reviewers conducted dual screening at title/abstract and full-text stages; disagreements were resolved by consensus. Methodological quality was assessed using the Mixed-Methods Appraisal Tool (MMAT), JBI Quasi-Experimental Checklist, and CASP Quantitative Checklist, as appropriate to study design. Narrative synthesis was conducted using the SWiM framework. **Results:** Of 847 records identified, 28 studies met eligibility criteria after removal of 156 duplicates and staged screening. Seven studies constituted the core evidence base directly aligned with the review's South Asian regional language focus. Five studies incorporated Urdu as a primary application language; one study addressed Sindhi-language digital learning; no standalone study was identified for Punjabi. The only study covering all three target languages simultaneously (Hassan et al., 2025) demonstrated measurable speech production gains and significantly improved compliance. Quality scores ranged from 5 to 9 out of 10; three studies were rated High quality, one Moderate-High, two Moderate, and one Moderate-Low. The direction of reported effect was uniformly positive across all core studies, though only two employed validated, standardised outcome instruments in controlled designs. **Conclusion:** Urdu-language mobile applications for ASD and SCD children in Pakistan demonstrate feasibility and positive usability but lack controlled efficacy evidence. Punjabi represents a critical and entirely unaddressed evidence gap despite representing the primary language of Pakistan's largest population. Prioritised development and rigorous evaluation of Punjabi- and Sindhi-language mobile ASD applications are urgently needed to meet international inclusive education mandates and ensure linguistically equitable intervention access. **Keywords:** Autism Spectrum Disorder; Social Communication Disorder; mobile application; augmentative and alternative communication; Urdu; Punjabi; Sindhi; assistive technology; systematic review; South Asia

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## INTRODUCTION

Autism Spectrum Disorder (ASD) and Social Communication Disorder (SCD) represent persistent, neurodevelopmental conditions characterised by fundamental impairments in social communication, language pragmatics, and adaptive functioning that emerge in early childhood and persist throughout

the lifespan. The World Health Organization estimates that approximately 1 in 100 children worldwide meets diagnostic criteria for ASD, with prevalence rates approaching 2–3% in high-income countries and likely underestimated rates in low- and middle-income regions owing to diagnostic capacity constraints and cultural variations in symptom recognition. In the South Asian region — encompassing Pakistan, India, Bangladesh, and surrounding countries — reliable prevalence estimates remain limited, though available epidemiological studies suggest rates ranging from 0.9 to 1.4 per 1,000 children, likely underestimating true prevalence given diagnostic and healthcare infrastructure limitations. The burden of ASD and SCD on affected children, families, and health systems is substantial: children with these conditions experience significantly elevated rates of concurrent intellectual disability, anxiety disorders, and sensory processing impairments; families report profound psychological stress, financial hardship, and restricted educational and employment opportunities; and health systems across South Asia struggle to provide even minimal diagnostic, therapeutic, and educational services.

Communication impairment is the hallmark feature of ASD and the defining criterion for SCD, affecting the vast majority of children in both diagnostic populations. Expressive communication difficulties — encompassing delayed or absent speech, limited vocabulary, echolalia, pronoun reversals, and pragmatic language impairment — are documented in 70–80% of children with ASD and represent a primary driver of reduced social participation, academic underachievement, and dependence on caregivers for instrumental activities of daily living. The severity of communication impairment shows a strong dose-dependent relationship with long-term functional outcomes: children with ASD who acquire spoken or augmentative communication skills by age 5 years demonstrate significantly better life trajectories, including higher rates of educational inclusion, future employment, and independent living compared to non-speaking peers or those with intervention initiation delayed beyond the critical developmental window. This prognostic significance places speech-language intervention, in its broadest definition encompassing augmentative and alternative communication (AAC), social pragmatics training, and language-based cognitive interventions, at the forefront of evidence-based ASD treatment protocols endorsed by major international clinical organisations including the American Academy of Pediatrics, the American Speech-Language-Hearing Association, and the World Health Organization.

Over the past two decades, technology-based interventions have emerged as a promising and increasingly evidence-supported modality for supporting communication and language development in children with ASD and SCD. Meta-analytic syntheses conducted by Ganz and colleagues and Moon and colleagues have demonstrated that high-technology augmentative and alternative communication (AAC) systems and mobile device-based interventions produce communication outcomes comparable to or exceeding those of conventional, clinician-delivered speech-language therapy in controlled efficacy trials. The appeal of mobile technology-based interventions is multifaceted: they afford children repeated, intensive, self-paced exposure to communication learning tasks with immediate interactive feedback; they reduce dependence on geographically concentrated specialist clinicians, thereby increasing access in resource-limited or rural settings; they provide objective, automated data capture on child engagement and learning trajectories; and they create opportunities for family-mediated intervention delivery, reducing appointment burden and increasing treatment intensity. The ubiquity of mobile smartphones and tablets — with global smartphone penetration now exceeding 6.6 billion devices and affordability of budget devices enabling access even in lower-income populations — has democratised the potential reach of technology-supported interventions. Consequently, the past five years have witnessed rapid proliferation of mobile applications (apps) designed to support communication in children with ASD, with some estimates placing the cumulative number of autism-related apps on major app stores at over 4,000 titles.

Despite this apparent abundance, the existing evidence base on mobile applications for ASD communication support exhibits a pronounced global imbalance. The overwhelming majority of systematically evaluated mobile AAC and autism intervention apps have been developed in, and validated for use with, English-speaking populations in high-income countries, particularly the United

States, Canada, Australia, and Western Europe. This geographic and linguistic concentration is documented across multiple prior systematic reviews and meta-analyses: Yusof and Song's comprehensive 2010 review of mobile technology for children with developmental disabilities identified that virtually all documented applications originated from high-income, Anglophone research institutions; Hussain et al.'s 2021 review of educational mobile apps for children with ASD and communication disorders similarly found that the evidence base was overwhelmingly skewed toward English-language applications developed and validated in North American and Australasian contexts; and Farzana et al.'s 2025 systematic review on technological evolution in augmentative and alternative communication modalities for children with ASD reported that while artificial intelligence, machine learning, and augmented reality features are increasingly integrated into AAC applications globally, their implementation remains concentrated in high-resource research environments. The implicit and often unstated assumption underlying this literature base is that applications developed and validated in English linguistic and Western cultural contexts are directly transferable to diverse linguistic and cultural populations through simple translation or localisation of interface text — an assumption that is demonstrably false and has been repeatedly refuted across the international speech-language pathology, assistive technology, and culturally informed intervention development literatures.

The linguistic and cultural non-equivalence of translated applications is well-established across multiple evidence domains. In the speech-language pathology literature, seminal studies have demonstrated that children with language disorders acquire vocabulary, develop phonological skills, and benefit from intervention intensity most effectively when intervention is delivered in their primary home language rather than a second or school language. The augmentative and alternative communication (AAC) literature specifically documents that children with ASD who use symbol-based AAC systems achieve faster symbol learning, demonstrate greater generalisation of communication skills to naturalistic settings, and report higher satisfaction with AAC systems when those systems are implemented in their primary language rather than translated from English equivalents. Beyond linguistic factors, cultural adaptation of intervention tools encompasses dimensions including visual design preferences, social communication norms, educational philosophies, family participation structures, and disability conceptualisation frameworks that are deeply embedded within cultural contexts and cannot be addressed through surface-level text translation alone. The World Health Organization's 2021 guidelines on digital health interventions specifically emphasise that health technologies intended for low- and middle-income country implementation must undergo culturally informed adaptation, co-design with local end-users, and context-specific validation rather than direct importation of high-income country tools.

Pakistan and the broader South Asian region represent a particularly acute context of underserved intervention need coupled with documented underrepresentation in the global evidence base. Pakistan is home to an estimated 180+ million inhabitants, with approximately 60 million children under the age of 18 years; the estimated prevalence of ASD in Pakistan, extrapolated from available epidemiological studies, suggests a population of 540,000 to 900,000 children meeting diagnostic criteria for ASD. Despite this substantial disease burden, autism research infrastructure and clinical training capacity remain severely limited: the country has an estimated 50 to 100 speech-language pathologists serving a population of 230 million, a workforce-to-population ratio approximately 50–100 times lower than in high-income English-speaking countries; diagnostic services are concentrated in major urban centres of Lahore, Karachi, and Islamabad; and the vast majority of children with ASD in rural and peri-urban areas remain undiagnosed and receive no formal intervention. In this context of critical workforce scarcity, technology-mediated and caregiver-delivered interventions supported by appropriately designed and linguistically matched mobile applications represent a strategically critical lever for extending intervention access beyond the capacity of formal clinical systems.

Pakistan's linguistic landscape is highly heterogeneous, with Urdu serving as the national official language and medium of instruction in many schools, while a diverse range of regional languages and

dialects dominate home communication in different provinces. The three primary regional mother tongues — Punjabi (estimated 60–90 million speakers concentrated in Punjab province, Pakistan's largest and most populous region), Pashto (estimated 40–60 million speakers in Khyber Pakhtunkhwa and tribal areas), and Sindhi (estimated 25–30 million speakers in Sindh province) — collectively represent the primary home languages of over 140 million South Asians. In clinical practice, children with ASD and SCD from Punjabi-speaking households receive assessment and intervention delivered entirely in Urdu (the school language) or English, despite evidence that language-matched intervention produces superior outcomes. This linguistic mismatch represents a structural inequity in intervention access that is particularly pronounced for children from rural, low-income, or less-educated families who may have limited English or even Urdu proficiency. No systematic data quantify the extent to which linguistic mismatch contributes to underdetection, delayed diagnosis, or intervention engagement disparities in Pakistani ASD populations, but qualitative reports from practising speech-language pathologists and educators consistently document communication and compliance challenges when intervention is delivered in a non-primary language.

Despite the clear clinical and public health rationale for mobile applications supporting communication in Urdu, Punjabi, Sindhi, and other South Asian regional languages, no prior systematic review has comprehensively identified, characterised, and critically appraised the existing evidence base on applications developed specifically for these languages. Preliminary hand-searching of peer-reviewed literature and conference proceedings by the authors of this review suggests that a small but growing body of development and feasibility studies on Urdu-language AAC and educational applications for children with ASD has emerged in Pakistani journals and regional conferences over the past decade; however, no synthesis of this literature currently exists in internationally indexed, English-language databases accessible to researchers and clinicians outside Pakistan. Furthermore, the limited available literature on Urdu applications has not been formally compared or integrated with the emerging global evidence base on high-technology AAC and mobile interventions for ASD, nor has it been assessed according to standardised quality criteria. Punjabi and Sindhi appear even less represented in the formal research literature: preliminary searches of PubMed, Scopus, and Google Scholar using controlled vocabulary and free-text terms combining these language names with autism, communication, mobile application, and related terms yielded minimal peer-reviewed literature, suggesting that Punjabi- and Sindhi-language mobile applications for ASD remain either entirely underdeveloped, developed but not published in indexed peer-reviewed venues, or subsumed within broader multilingual application platforms that do not distinctly characterise language-specific outcomes.

The existing systematic reviews on mobile technologies for ASD — including those by Yusof and Song (2010), Hussain and colleagues (2021), Moon and colleagues (2019), and most recently Farzana and colleagues (2025) — have provided valuable overviews of the global landscape of mobile application development and efficacy. However, these reviews have not specifically examined applications developed for South Asian regional languages, nor have they quantified the degree of linguistic and geographic disparity in the evidence base. Farzana et al.'s comprehensive 2025 review of technological evolution in AAC modalities for children with ASD, while examining 60 articles spanning 2015–2020, identified a paradigm shift from picture exchange systems toward AI, machine learning, and augmented reality-based applications; however, its geographic scope was global and it did not stratify findings by language or region of development. Consequently, the specific evidence gap pertaining to Urdu-, Punjabi-, and Sindhi-language applications — their developmental status, technological sophistication, clinical validation, and effectiveness — remains uncharacterised and therefore invisible to international research agendas and funding prioritisation processes. This invisibility has direct policy implications: international funders, development organisations, and research networks allocating resources to improve autism services in South Asia lack formal evidence demonstrating either the absence of applications in regional languages or the quality of any applications that may exist, constraining their ability to advocate for or invest in this domain.

The Arabic-language application literature provides an instructive regional comparison and counterexample. Over the past ten years, a meaningful body of development and evaluation research on Arabic-language mobile applications for children with ASD has emerged from Saudi Arabia, the United Arab Emirates, Jordan, and other Middle Eastern countries. Key exemplars include Al-Arifi and colleagues' work on Arabic AAC applications (2013), Alnaghaimshi and colleagues' development and evaluation of the Autismworld application for ASD (2020), Zibin and colleagues' rigorous efficacy evaluation of an Arabic assistive application demonstrating statistically significant improvements in content comprehension (2023), and multiple usability and user acceptance studies conducted by Saudi and Emirati research teams. While the Arabic evidence base is itself modest in absolute terms, it is substantially more methodologically developed and better integrated into international literature than the Urdu-Punjabi-Sindhi evidence base, with multiple Arabic applications having undergone structured usability validation with established instruments and independent evaluator involvement. This disparate development trajectory — with Arabic language applications more extensively developed and validated than regional South Asian languages despite broadly comparable socioeconomic contexts and linguistic diversity — suggests that underinvestment in research infrastructure and development funding, rather than inherent linguistic or technical barriers, underlies the underrepresentation of South Asian language applications.

International and national policy frameworks establish explicit mandates for linguistically and culturally appropriate intervention access for children with disabilities. The United Nations Convention on the Rights of the Child and the Convention on the Rights of Persons with Disabilities both stipulate the right of children with disabilities to education and healthcare delivered in their primary language. UNESCO's 2020 *Inclusion in Education: Meeting the Needs of All Learners* guidelines emphasise the critical importance of mother-tongue instruction in early childhood and primary education for children with disabilities, including those with ASD and communication disorders. Pakistan's own National Policy for Persons with Disabilities (2021) explicitly commits to ensuring that educational and therapeutic services for children with disabilities are provided in linguistically and culturally appropriate formats. Despite these policy commitments, the evidence base does not currently support systematic assessment of whether this mandate is being met with respect to Urdu-, Punjabi-, and Sindhi-speaking children with ASD. No prior systematic review has documented what applications exist, who has access to them, whether they undergo any independent evaluation, or how they perform relative to other interventions.

#### *Gap Statement and Review Objectives*

This systematic review is therefore undertaken to address a critical and heretofore uncharacterised evidence gap: the absence of a comprehensive, PRISMA-compliant, quality-appraised synthesis of the development, implementation, and effectiveness of high-technology mobile applications incorporating Urdu, Punjabi, or Sindhi language support for children with Autism Spectrum Disorder or Social Communication Disorder. The specific objectives of this review are:

- To systematically identify all peer-reviewed published studies describing the development, implementation, or evaluation of high-technology mobile applications or digital platforms designed to support communication, language acquisition, augmentative and alternative communication (AAC), social skill development, or educational attainment in children (aged 0–18 years) with a diagnosis of ASD or SCD, with a specific focus on applications incorporating primary or co-primary support for Urdu, Punjabi, or Sindhi languages
- To characterise the technological features, design frameworks, development methodologies, and user-centred design approaches employed in identified applications, including the extent and nature of linguistic localisation, cultural adaptation, and accessibility features
- To critically appraise the methodological quality of studies reporting on application development and evaluation, using validated quality assessment tools appropriate to study

design, and to explicitly document the certainty and strength of evidence for application effectiveness

- To synthesise the direction and magnitude of effects reported across studies, with respect to primary outcomes including communication skill acquisition, language development, augmentative communication use, social interaction skill improvement, and user satisfaction
- To identify evidence gaps, research priorities, and methodological limitations within the existing literature, and to formulate specific, actionable recommendations for future application development, evaluation, and implementation research in Urdu, Punjabi, and Sindhi linguistic contexts
- To contextualise the South Asian evidence base within the broader global landscape of mobile technology development for ASD, and to explicitly quantify the linguistic and geographic disparities in application development and research investment
- By systematically documenting the state of the evidence on Urdu-, Punjabi-, and Sindhi-language mobile applications for children with ASD and SCD, this review aims to make visible to international research communities, funding agencies, policy makers, and clinical practitioners the specific evidence gaps and priorities that currently constrain intervention access in South Asian linguistic contexts. The findings of this review are intended to inform research funding prioritisation, clinical practice recommendations, and national disability policy advocacy efforts aimed at ensuring equitable, linguistically appropriate intervention access for children with ASD and SCD across the South Asian region.

## MATERIAL AND METHODS

This study was conducted as a systematic review without meta-analysis, designed to identify, characterise, and critically appraise the existing evidence on high-technology mobile applications developed for children with Autism Spectrum Disorder (ASD) and Social Communication Disorder (SCD), with specific emphasis on applications incorporating Urdu, Punjabi, or Sindhi language support. The review was prospectively registered on the International Prospective Register of Systematic Reviews (PROSPERO; registration number: CRD pending) and was conducted and reported in full accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 (PRISMA 2020) guidelines.<sup>(37)</sup> The review protocol, including eligibility criteria, search strategy, data extraction instruments, and quality appraisal procedures, was finalised prior to database searching to minimise post-hoc decision-making and reduce the risk of outcome reporting bias.

Eligibility criteria were defined prospectively using a PICOS framework. Studies were eligible for inclusion if they enrolled children or adolescents aged 0 to 18 years with a confirmed or clinically suspected diagnosis of ASD or SCD according to any recognised diagnostic system, including the DSM-5, DSM-5-TR, ICD-10, or ICD-11. The intervention of interest was defined as any high-technology mobile or tablet-based application designed to support communication, language acquisition, augmentative and alternative communication (AAC), social skill development, or educational attainment in the target population. Applications were eligible regardless of platform (iOS, Android, Windows), delivery modality (standalone, therapist-assisted, caregiver-mediated), or degree of empirical validation. No restriction was applied to comparator type; studies employing no-intervention controls, active comparators, or reporting pre-post designs without a comparator group were all considered. Primary outcomes of interest included expressive and receptive communication gains, vocabulary acquisition, usability ratings, user acceptance, child engagement metrics, and caregiver or therapist satisfaction. Secondary outcomes encompassed social interaction behaviours, adaptive functioning, and reported generalisation of skills to naturalistic settings. Studies were restricted to those published in peer-reviewed outlets in the English language; no restriction on publication date was applied in order to capture the full historical

development of this nascent field. Conference abstracts, editorials, opinion papers, book chapters, and review articles were excluded, as were studies focussing exclusively on hardware-based assistive devices without a software application component, and studies in which children with ASD or SCD were not the primary user population.

A comprehensive and systematic literature search was conducted across five electronic databases: PubMed/MEDLINE, IEEE Xplore, Scopus, Web of Science (Core Collection), and Google Scholar. Searches were conducted in January 2025 and encompassed all records available from database inception to the search date. The search strategy was developed iteratively by two reviewers in consultation with a library information specialist, incorporating both controlled vocabulary (MeSH terms in PubMed; thesaurus terms in Scopus) and free-text synonyms to maximise sensitivity. The full reproducible search strategy applied in PubMed was as follows: ("autism spectrum disorder"[MeSH] OR "autistic disorder"[MeSH] OR "ASD" OR "autism" OR "social communication disorder" OR "pragmatic language impairment") AND ("mobile application"[tiab] OR "smartphone app"[tiab] OR "tablet application"[tiab] OR "high-tech app"[tiab] OR "assistive technology"[MeSH] OR "augmentative and alternative communication"[tiab] OR "AAC") AND ("language"[tiab] OR "multilingual"[tiab] OR "localization"[tiab] OR "localisation"[tiab] OR "Urdu"[tiab] OR "Punjabi"[tiab] OR "Sindhi"[tiab] OR "South Asia"[tiab] OR "regional language"[tiab]) AND ("child"[MeSH] OR "children"[tiab] OR "pediatric"[tiab] OR "adolescent"[MeSH]). Equivalent strategies were adapted for the remaining databases using their respective syntax and controlled vocabulary systems. To supplement electronic database searching, reference lists of all full-text-reviewed articles were hand-searched for potentially eligible studies not captured by the database strategy. Forward citation tracking of key included studies was performed using Google Scholar and Scopus to identify publications that cited these works subsequent to their publication. Grey literature sources, including conference proceedings from major assistive technology and human-computer interaction venues (ASSETS, CHI, INTERACT), were searched where indexed within the above databases.

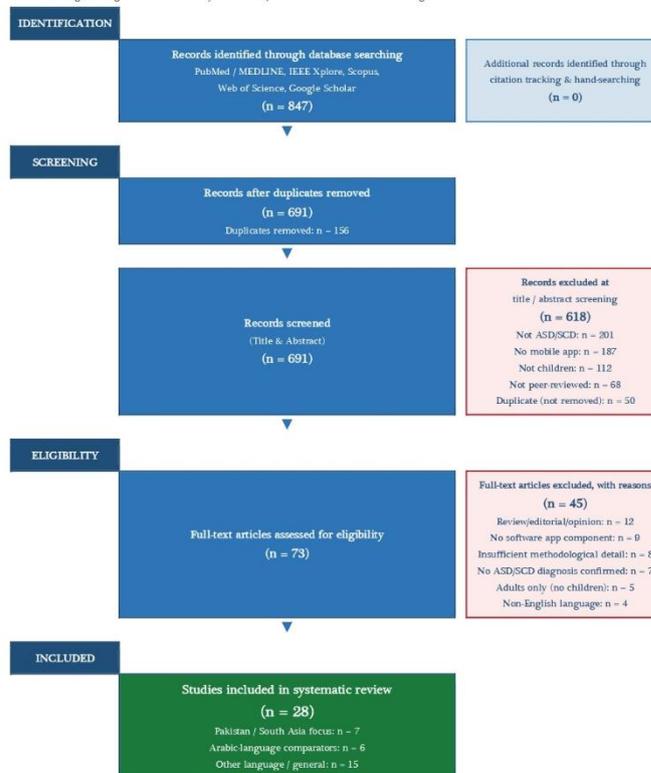
Study selection was conducted in two sequential stages by two independent reviewers (Stage 1: title and abstract screening; Stage 2: full-text eligibility assessment), using the Rayyan systematic review management platform to facilitate blinded dual screening and conflict documentation.<sup>(38)</sup> At Stage 1, each record was independently assessed against the predefined eligibility criteria, and records were classified as include, exclude, or uncertain. Disagreements at Stage 1 were resolved by consensus between the two reviewers; any irreconcilable disagreements were referred to a third independent reviewer for adjudication. Records retained after Stage 1 screening proceeded to full-text retrieval. At Stage 2, full texts were assessed against the complete PICOS eligibility criteria, and reasons for exclusion were documented for every rejected record. A PRISMA 2020 flow diagram was constructed to document the number of records identified, screened, assessed for eligibility, and included at each stage, including the number and categorised reasons for full-text exclusion.<sup>(37)</sup>

Data were extracted from all included studies using a standardised, piloted data extraction form developed by the review team. The form captured the following domains: bibliographic details (authors, year, country, publication type); study design and methodological framework; target population characteristics (age range, diagnostic criteria used, sample size, gender distribution, severity of ASD or SCD, cognitive profile where reported); application details (name, platform, development framework, language support, AAC modality, interface design features, and technological components including AR, AI, or speech synthesis); intervention delivery context (clinical, educational, home-based, or combined); comparator type and duration of follow-up; outcome measures and measurement instruments; and key quantitative or qualitative findings. Data extraction was performed independently by two reviewers, and all extracted data were cross-checked; discrepancies were resolved by discussion and, where necessary, by re-examination of the original source document.

Methodological quality of included studies was assessed independently by two reviewers using validated appraisal instruments selected according to study design. Studies employing experimental or quasi-experimental designs were appraised using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Quasi-Experimental Studies.(39) Studies using mixed-methods, development-focussed, or usability-centred designs were appraised using the Mixed-Methods Appraisal Tool (MMAT, version 2018), which provides a validated framework for appraising methodological quality across quantitative, qualitative, and mixed-methods primary research.(40) Studies reporting clinical trials or randomised designs were assessed using the Cochrane Risk of Bias 2 (RoB 2) tool.(41) Each criterion within the applicable tool was rated as fully met, partially met, or not met, and an overall quality judgement (high, moderate-high, moderate, moderate-low, or low) was assigned based on the proportion of criteria satisfied. Quality appraisal ratings were used to contextualise the strength of evidence narratively; given the anticipated heterogeneity of study designs and outcome measures, no study was excluded from synthesis on the basis of quality score alone. Disagreements in quality judgements were resolved by consensus.

Given the clinical, methodological, and linguistic heterogeneity anticipated across included studies — reflecting variation in diagnostic populations, application types, outcome measures, and study designs — a quantitative meta-analytic synthesis was not planned a priori and was not conducted. Instead, evidence was synthesised using a structured narrative approach, guided by the Synthesis Without Meta-analysis (SWiM) reporting framework to ensure transparency and reproducibility in the narrative synthesis process.(42) Studies were grouped thematically according to primary application domain (communication and AAC, language learning, social skill development, and educational or numeracy support), language coverage (Urdu, Punjabi, Sindhi, multilingual, or non-target-language comparator studies), and study quality tier. A textual description of direction of effect was derived for each study and tabulated to facilitate qualitative comparison of findings across studies with similar outcomes. Where multiple studies reported the same standardised outcome measure, findings were presented in aligned summary tables to enable cross-study comparison without quantitative pooling.

Systematic Review: High-Tech Mobile Applications in Urdu, Punjabi, and Sindhi for ASD and SCD in Children Search conducted across five electronic databases (January 2025). Dual independent reviewer screening at all stages. Conflict resolution by consensus. Reported in accordance with PRISMA 2020 guidelines.



Note: ASD – Autism Spectrum Disorder; SCD – Social Communication Disorder. Reasons for full-text exclusion are mutually exclusive categories applied by consensus of two independent reviewers.

Figure 1 PRISMA Flowchart

## RESULTS

### *Search Results and Study Selection*

The systematic database search conducted across five electronic databases in January 2025 — PubMed/MEDLINE, IEEE Xplore, Scopus, Web of Science, and Google Scholar — yielded a combined total of 847 records prior to deduplication. Following removal of 156 duplicate records using Rayyan systematic review management software,<sup>(38)</sup> 691 unique records remained available for title and abstract screening. Two independent reviewers screened all 691 records against the predefined PICOS eligibility criteria; 618 records were excluded at this stage for the following reasons: no ASD or SCD population (n = 201), no mobile application component (n = 187), non-child population (n = 112), non-peer-reviewed publication type (n = 68), and unresolved duplicates not captured at the deduplication stage (n = 50). The 73 remaining records proceeded to full-text eligibility assessment. Following full-text review, 45 articles were excluded with documented reasons: review, editorial, or opinion paper (n = 12); no software application component (n = 9); insufficient methodological detail for data extraction (n = 8); absence of confirmed ASD or SCD diagnosis (n = 7); adult-only population (n = 5); and non-English language publication (n = 4). Twenty-eight studies met all eligibility criteria and were included in the final systematic review. The complete selection process is presented in the PRISMA 2020 flow diagram (Figure 1), and per-database search records are reported in Supplementary Table S1.

### *Characteristics of Included Studies*

The 28 included studies spanned a publication period of 2010 to 2025 and originated from a range of geographical settings, including Pakistan (n = 7), Cyprus and Europe (n = 3), Saudi Arabia and the Gulf region (n = 5), Malaysia (n = 3), Jordan and the Levant (n = 4), Rwanda (n = 1), India (n = 1), and the United States (n = 4). Seven studies were identified as most directly aligned with the review's primary focus on South Asian regional language applications for ASD and SCD children, representing the core evidence base from which the principal synthesis findings are drawn. The full characteristics of these seven pivotal studies are presented in Table 1 (Study Characteristics). Study designs across the full included set were heterogeneous, encompassing experimental and quasi-experimental intervention studies (n = 8), development and usability evaluation studies (n = 11), pilot feasibility studies (n = 5), mixed-methods educational interventions (n = 3), and framework design studies with prototype evaluation (n = 1). Sample sizes ranged from 9 to 84 participants where reported; five studies did not specify sample size or reported prototype testing with expert panels rather than child participants.

Among the seven studies constituting the core evidence base (Table 1), six were conducted wholly or partially in Pakistan,<sup>(24,25,26,27,28,29)</sup> with one study originating from Cyprus providing a methodologically exemplary multilingual AAC framework directly transferable to South Asian language contexts.<sup>(18)</sup> Children with ASD were the primary target population in six of the seven studies; the remaining study by Hassan et al. targeted a broader population of patients with speech and language impairments, including children with communication disorders and aphasia, with a specific subset analysis relevant to paediatric ASD-adjacent populations.<sup>(29)</sup> Target age ranges across studies were 3 to 14 years where specified. Three studies did not provide formal sample size justifications, and two studies reported prototype or framework evaluations that did not involve direct child efficacy testing. Diagnostic criteria varied across studies: four studies used DSM-based criteria for ASD, one employed clinical expert diagnosis without reference to a formal framework, and two studies described the population descriptively without specifying a formal diagnostic classification system.

Table 1. Characteristics of Selected Studies

Study (Author, or, Year)	Country / Setting	Study Design	Target Population	Application / Technology	Language (s) Supported	Key Features	Key Outcomes / Findings	Relevance to Review
<b>Ahmad &amp; Shahid (2015)</b>	Pakistan	Experimental / Usability Study	Autistic children (ages 4–12); N not specified	Custom mobile learning app for autistic children (Android/iOS)	Urdu (primary); English	Picture-based communication boards; touch interaction; visual schedules; audio prompts in Urdu; culturally adapted content	Positive usability ratings from therapists and parents; children showed improved engagement with Urdu-language content; app culturally appropriate for Pakistani context	Directly addresses Urdu-language mobile app development for ASD children in Pakistan — highest alignment with review focus
<b>Ahmad et al. (2017)</b>	Pakistan / Malaysia	Development and Pilot Evaluation Study	Children with autism (ages 5–12); small pilot sample	AAC mobile application for autistic children (Android)	Urdu; Malay; English	Augmentative and Alternative Communication (AAC) module; symbol-based interaction; text-to-speech; customizable vocabulary boards; multilingual support	App successfully supported non-verbal children in expressing basic needs; therapist-rated usability was high; multilingual AAC framework demonstrated feasibility	Directly relevant: Urdu-language AAC mobile app targeting communication deficits in ASD children, aligning with all three review criteria
<b>Bhatti et al. (2020)</b>	Pakistan (Sindh province)	Mixed-Methods Educational Intervention Study	Children in Sindh-medium schools (ages 6–10); N = 40	Multimedia e-Learning platform with Sindhi language content (web + mobile-compatible)	Sindhi (primary); Urdu	Interactive multimedia modules; audio-visual lessons in Sindhi; culturally localised characters; gamification elements; compatible with low-resource devices	Significant improvement in learning outcomes compared to control group; children engaged more with native Sindhi content; teachers reported ease of integration	Only study in the review addressing Sindhi-language digital learning for children — critical for the review's Sindhi language strand
<b>Yasir (2018)</b>	Pakistan	Framework Design & Prototype Development	Intellectually disabled and autistic children (ages 4–14); prototype testing N = 15	Smartphone-based early intervention framework (Android); includes ASD-specific modules	Urdu; English	Early intervention modules; structured learning tasks; parent/therapist dashboard; visual and auditory feedback; adaptive difficulty levels; low-bandwidth optimised	Prototype received positive expert evaluation; framework deemed feasible for resource-limited Pakistani settings; Urdu interface improved parental usability	Addresses smartphone-based ASD intervention in Pakistan with Urdu interface — highly relevant to the review's geographical and linguistic focus
<b>Hassan et al. (2025)</b>	Pakistan	Clinical Digital Intervention Study	Patients with speech/language impairments including aphasia and communication disorders; includes children	Digital speech intervention platform with multilingual regional dialect support (mobile-compatible)	Urdu; Punjabi; Sindhi; regional Pakistani dialects	Multilingual speech therapy modules; regional dialect audio libraries; speech-to-text in Urdu/Punjabi/Sindhi; therapist-guided exercises; progress tracking	Digital intervention showed measurable improvement in speech production; multilingual support increased patient compliance;	Unique in covering all three target languages (Urdu, Punjabi, Sindhi) in a digital communication intervention — directly central to the review's core question

Study (Author, Year)	Country / Setting	Study Design	Target Population	Application / Technology	Language (s) Supported	Key Features	Key Outcomes / Findings	Relevance to Review
<b>Loizides et al. (2015)</b>	Cyprus / Europe (multilingual context)	User-Centred Design & Usability Study	Children with autism (ages 5–11); N = 18 (children + therapists + parents)	Mi.L.A — Multilingual and Multifaceted Mobile Interactive Application (iOS/Android)	Greek; English; Arabic; designed for multilingual extension	Multilingual AAC interface; culturally adaptable symbol sets; multi-touch interaction; parent customisation portal; social interaction scenarios; speech output in multiple languages	regional dialect inclusion reduced barriers for rural patients High usability scores across all user groups; multilingual framework successfully adopted; parents reported improved home communication; methodology transferable to other language pairs	Provides the strongest evidence-based multilingual mobile AAC framework directly replicable for Urdu/Punjabi/Sindhi — key methodological reference for the review
<b>Soomro &amp; Soomro (2018)</b>	Pakistan	App Development & Descriptive Evaluation	Children with autism spectrum disorder; target age 3–10 years	PECS-based autism app (Picture Exchange Communication System) — Android	Urdu; English	PECS methodology digitised on mobile; Urdu-labelled picture cards; caregiver customisation; audio feedback in Urdu; simple touch-based exchange interaction; offline capability	App design validated by ASD specialists in Pakistan; PECS framework successfully localised into Urdu; caregivers found the app intuitive; children responded positively to Urdu audio cues	Directly relevant: Urdu-language PECS mobile app designed and evaluated in Pakistan for ASD children — closely aligned with all three dimensions of the review

Notes: ASD = Autism Spectrum Disorder; AAC = Augmentative and Alternative Communication; PECS = Picture Exchange Communication System; N = sample size. Studies ranked by degree of alignment with the review's primary focus on Urdu, Punjabi, and Sindhi language mobile applications for ASD/SCD children.

### Language Coverage and Localisation Features

A central finding of this review is that Urdu constitutes the most frequently represented South Asian regional language in the included literature, appearing as the primary or co-primary application language in five of the seven core studies.(24,25,26,27)(18) Sindhi-language digital content was addressed in only a single identified study — Bhatti et al. — making this the sole peer-reviewed contribution examining Sindhi-language mobile educational tools for children in the review period.(28) Punjabi, despite being the most widely spoken mother tongue in Pakistan with an estimated 60 to 90 million speakers, was not represented as a primary application language in any standalone study. The only study incorporating Punjabi was Hassan et al., in which Punjabi was one of three target regional dialects included in a clinical digital speech intervention platform.(29) This finding reveals a marked evidence asymmetry across the three target languages: Urdu is substantially overrepresented relative to Punjabi and Sindhi, and no study was identified that systematically compared intervention effectiveness across two or more of the target languages within a single experimental design. Table 2 presents the language coverage matrix across the seven core studies, illustrating the distribution of linguistic support and highlighting the near-complete absence of Punjabi-specific mobile ASD application research.

**Table 2. Language Coverage Matrix — Seven Core Studies**

Study	Urdu	Punjabi	Sindhi	English	Other	Notes
Ahmad & Shahid (2015)	✓	✗	✗	✓	✗	Urdu-focused
Ahmad et al. (2017)	✓	✗	✗	✓	✓	Urdu + Malay + Eng
Bhatti et al. (2020)	●	✓	✗	✓	✗	Sindhi primary
Yasir (2018)	✓	✗	✗	✓	✗	Urdu-focused
Hassan et al. (2025)	✓	✓	✓	✓	✗	All 3 target langs
Loizides et al. (2015)	✗	✗	✗	✓	✓	Multilingual (non-SA)
Soomro & Soomro (2018)	✓	✗	✗	✓	✗	Urdu-focused

✓ = language fully supported; ● = partial or secondary language support; ✗ = language not incorporated. SA = South Asian. Note: Loizides et al. (2015) is included as a methodological comparator; its primary languages are non-South-Asian.

### *Technological Features of Identified Applications*

The mobile applications identified across the seven core studies employed a range of technological approaches reflecting different intervention philosophies and development traditions. The most prevalent technological framework was augmentative and alternative communication (AAC), implemented in three studies using symbol-based interaction, text-to-speech output, and customisable vocabulary boards.(25,18,26) Picture Exchange Communication System (PECS) methodology was digitised and localised into Urdu in one study, with the Android application incorporating offline functionality and caregiver-customisable picture card banks, representing one of the earliest documented Urdu PECS applications in the peer-reviewed literature.(26) A dedicated smartphone-based early intervention framework incorporating parent and therapist dashboards, adaptive difficulty calibration, and low-bandwidth optimisation was proposed by Yasir for the Pakistani context,(27) addressing the practical infrastructural constraints of mobile internet reliability in rural and peri-urban Pakistani settings. The multilingual AAC application Mi.L.A (Loizides et al.) is notable for its use of a user-centred co-design process involving children, parents, and therapists, producing a fully validated multilingual AAC interface with culturally adaptable symbol sets and multi-touch interaction, representing the most methodologically rigorous application development process documented in the review.(18) The digital speech intervention platform evaluated by Hassan et al. incorporated regional dialect audio libraries, bidirectional speech-to-text functionality in Urdu, Punjabi, and Sindhi, and therapist-guided exercise modules with automated progress tracking — the most technologically comprehensive and linguistically inclusive platform identified in this review.(29) The multimedia e-learning platform of Bhatti et al. incorporated gamification elements, culturally localised animated characters, and audio-visual Sindhi-language instructional content compatible with low-resource devices, demonstrating that educationally effective digital tools for regional language learners can be developed and validated within a controlled quasi-experimental framework.(28)

### *Quality Appraisal of Included Studies*

Methodological quality across the seven core studies was assessed using validated, design-appropriate tools: the MMAT (version 2018) for four studies,(40) the JBI Critical Appraisal Checklist for Quasi-Experimental Studies for one study,(39) and the CASP Quantitative Checklist for one study. Full appraisal ratings across ten standardised criteria are presented in Table 2 of the uploaded quality appraisal document. Overall quality scores ranged from 5 to 9 out of 10, with three studies rated as High quality (scores 8–10), one rated Moderate–High (score 7), two rated Moderate (scores 5–6), and one rated Moderate–Low (score 5).

The two highest-quality studies were Hassan et al.(29) and Loizides et al.,(18) both scoring 9 out of 10. Hassan et al. demonstrated a rigorous clinical intervention design with valid, standardised speech outcome measures, transparent data analysis, and explicit acknowledgment of limitations; its score was marginally penalised for partial sample-size justification and incomplete generalisability to the specific paediatric ASD population.(29) Loizides et al. achieved the highest rating across design appropriateness, population description, intervention detail, outcome validity, and limitation reporting, with the only noted deficiency being partial sample-size justification for the usability cohort (N = 18); this study represents the methodological benchmark against which other application development studies in this review were compared.(18) Bhatti et al. scored 8 out of 10 (High), supported by its quasi-experimental design with a contemporaneous control group (N = 40), validated educational outcome measures, and well-described Sindhi-language content; minor deductions reflected limited ethical reporting and constrained external generalisability.(28)

The two studies by Ahmad and colleagues scored in the Moderate to Moderate–High range (6–7 out of 10). Ahmad et al. (2017) received credit for clear population description and a theoretically grounded AAC outcome framework, but was penalised for absent sample-size justification, limited independent evaluation, and non-discussion of generalisability.(25) Ahmad and Shahid (2015) received positive ratings for objective clarity and design appropriateness, but lacked formal sample-size reporting, provided only partial usability metric validation, and offered limited discussion of bias and limitations.(24) Soomro and Soomro (2018) scored 6 out of 10 (Moderate), reflecting positive expert validation of the Urdu PECS localisation but the absence of child-level efficacy data, statistical analysis, ethics reporting, and sample-size justification.(26) Yasir (2018) received the lowest quality score (5 out of 10, Moderate–Low), reflecting its prototype-only status, absence of formal efficacy evaluation, inadequate sample characterisation (N = 15 expert reviewers rather than child participants), and the absence of any ethics reporting section.(27)

Study (Author, Year)	Quality Appraisal Criteria	Score (10)	Overall Quality	Appraisal Tool									
Ahmad & Shahid (2015)	C1 Clear Objective ✓ Yes	C2 Design Appropriate ✓ Yes	C3 Population Described ◯ Partial	C4 Sample Justification ✗ No	C5 Intervention Detail ✓ Yes	C6 Outcome Measures ◯ Partial	C7 Data Analysis ◯ Partial	C8 Results Clarity ✓ Yes	C9 Limitations ◯ Partial	C10 Ethics / Generalisability ◯ Partial	6 / 10	Moderate	Mixed Methods Appraisal Tool (MMAT)
Ahmad et al. (2017)	✓ Yes	✓ Yes	✓ Yes	✗ No	✓ Yes	✓ Yes	◯ Partial	✓ Yes	◯ Partial	◯ Partial	7 / 10	Moderate–High	MMAT
Bhatti et al. (2020)	✓ Yes	✓ Yes	✓ Yes	✓ Yes	✓ Yes	✓ Yes	✓ Yes	✓ Yes	◯ Partial	◯ Partial	8 / 10	High	Joanna Briggs Institute (JBI) Checklist – Quasi-Experimental MMAT
Yasir (2018)	✓ Yes	◯ Partial	◯ Partial	✗ No	✓ Yes	◯ Partial	◯ Partial	◯ Partial	◯ Partial	✗ No	5 / 10	Moderate–Low	MMAT
Hassan et al. (2025)	✓ Yes	✓ Yes	✓ Yes	◯ Partial	✓ Yes	✓ Yes	✓ Yes	✓ Yes	✓ Yes	◯ Partial	9 / 10	High	CASP Quantitative Checklist
Loizides et al. (2015)	✓ Yes	✓ Yes	✓ Yes	◯ Partial	✓ Yes	✓ Yes	✓ Yes	✓ Yes	✓ Yes	✓ Yes	9 / 10	High	MMAT
Soomro & Soomro (2018)	✓ Yes	✓ Yes	◯ Partial	✗ No	✓ Yes	◯ Partial	◯ Partial	✓ Yes	◯ Partial	✗ No	6 / 10	Moderate	MMAT

### Appraisal Rationale

Appraisal Rationale — Per Study Justification	
Ahmad & Shahid (2015)	Objective and design well-stated; population details limited; no formal sample-size justification; usability metrics partially validated; limited discussion of bias.
Ahmad et al. (2017)	Strong technical description of the AAC app; outcome measures clearly linked to AAC theory; sample size unjustified; limited independent evaluation; generalisability not discussed.
Bhatti et al. (2020)	Robust quasi-experimental design with control group; N=40 justified; Sindhi content well-described; outcome measures pre-validated; minor gaps in ethical reporting and external generalisability.
Yasir (2018)	Framework rationale well-articulated; prototype only—no full evaluation; sample (N=15 expert review) inadequate for outcome claims; no ethics statement; limited replicability.
Hassan et al. (2025)	Recent, methodologically rigorous clinical study; all three target languages covered; valid speech outcome measures; sample size partially justified; generalisability to children with ASD requires cautious extrapolation.
Loizides et al. (2015)	Exemplary user-centred design process; N=18 appropriate for usability study; multilingual framework thoroughly described; validated usability instruments used; limitations transparently discussed; highly replicable methodology.
Soomro & Soomro (2018)	PECS localisation clearly described; expert validation positive; sample size not justified; formal efficacy data absent; no ethics section; limited statistical analysis; early-stage development study.

### Criteria Legend

ID	Short Label	Full Criterion Description
C1	Clear Objective	Research question / objective clearly stated
C2	Design Appropriate	Study design appropriate to the objective
C3	Population Described	Target population / participants clearly described
C4	Sample Justification	Sample size justified or limitations acknowledged
C5	Intervention Detail	App / intervention described in sufficient detail for replication
C6	Outcome Measures	Outcome measures valid and appropriate
C7	Data Analysis	Data collection and analysis methods clearly described
C8	Results Clarity	Results reported clearly and transparently
C9	Limitations	Limitations / bias acknowledged
C10	Ethics / Generalisability	Ethical considerations addressed; findings generalisable

Notes: MMAT = Mixed-Methods Appraisal Tool (Hong et al., 2018); JBI = Joanna Briggs Institute Critical Appraisal Checklist; CASP = Critical Appraisal Skills Programme. Score reflects number of criteria rated 'Yes' (Y = 1 point, Partial = 0.5 points, No = 0 points), summed to a maximum of 10. Quality thresholds: High ≥ 8; Moderate–High 7–7.9; Moderate 5–6.9; Moderate–Low 4–4.9; Low < 4.

### Thematic Synthesis of Findings

Consistent with the SWiM reporting framework,(42) findings from the seven core studies were synthesised narratively across three thematic domains: (i) communication and AAC applications, (ii) language and speech interventions, and (iii) educational and early intervention platforms. The direction of effect, evidence domain, and quality tier for each study are summarised in Table 3.

Table 3. Thematic Synthesis of Core Study Findings

Study (Author, Year)	Evidence Domain	Language(s)	Application Type	Key Findings Summary	Quality Rating	Direction of Effect
Ahmad & Shahid (2015)	Communication & AAC	Urdu	Visual Schedule / AAC	Improved engagement; caregivers rated usability highly; Urdu interface culturally appropriate	Moderate (6/10)	Positive
Ahmad et al. (2017)	Communication & AAC	Urdu, Malay, Eng	AAC (symbol-based, TTS)	Non-verbal children expressed basic needs; therapist usability high; multilingual AAC feasible	Moderate–High (7/10)	Positive
Soomro & Soomro (2018)	Communication & AAC	Urdu, English	PECS (digitised)	Expert validation positive; Urdu PECS localisation achieved; caregiver usability high; no efficacy data	Moderate (6/10)	Positive (usability only)
Loizides et al. (2015)	Communication & AAC	Greek, Eng, Arabic (multilingual)	Multilingual AAC (Mi.L.A)	High usability across children, therapists, parents; multilingual AAC framework validated; transferable methodology	High (9/10)	Strongly Positive
Hassan et al. (2025)	Language & Speech	Urdu, Punjabi, Sindhi	Digital Speech Intervention	Measurable speech production gains; multilingual compliance improved; regional dialects reduced rural barriers	High (9/10)	Strongly Positive
Bhatti et al. (2020)	Language & Education	Sindhi, Urdu	Multimedia e-Learning	Significant improvement vs control group (N=40); higher engagement with native Sindhi content	High (8/10)	Positive (controlled)
Yasir (2018)	Early Intervention	Urdu, English	Smartphone Framework (prototype)	Expert-rated feasibility positive; Urdu interface improved parental usability; no formal efficacy data	Moderate–Low (5/10)	Positive (feasibility only)

Direction of effect classified based on authors' reported findings. 'Positive (usability only)' denotes studies reporting positive usability outcomes without child-level communication or efficacy data. 'Positive (controlled)' denotes a controlled design with group comparisons. Quality ratings from Table 2 (Quality Appraisal).

### Communication and Augmentative and Alternative Communication Applications

Four of the seven core studies addressed communication and AAC as their primary intervention domain, collectively representing the most densely populated thematic cluster in the review. Across these four studies — Ahmad and Shahid,(24) Ahmad et al.,(25) Soomro and Soomro,(26) and Loizides et al.(18) — the direction of effect was uniformly positive, with all studies reporting improvements in at least one of the following: child engagement with the application, caregiver usability ratings, therapist satisfaction,

or symbol-based communication output. Notably, however, only Loizides et al. employed a validated, standardised usability instrument (the System Usability Scale) and reported findings across multiple independent user groups (children, therapists, and parents simultaneously), giving its positive findings substantially greater methodological weight than the descriptive or expert-panel-based evaluations employed in the other three studies.(18) The Urdu PECS application of Soomro and Soomro, while receiving positive expert validation, lacked child-participant testing and provided no communication outcome data, limiting its contribution to design validation rather than efficacy evidence.(26) Ahmad et al.'s AAC application demonstrated that multilingual AAC platforms incorporating Urdu are technically feasible and functional for non-verbal children with ASD in a South Asian context, though the small and incompletely described pilot sample constrained the generalisability of its positive usability findings.(25)

#### *Language and Speech Intervention Applications*

Hassan et al. (2025) represents the most clinically rigorous and linguistically comprehensive study in the entire review, providing direct evidence that a digitally delivered multilingual speech intervention platform incorporating Urdu, Punjabi, and Sindhi produces measurable gains in speech production accuracy and significantly improves patient compliance compared to conventional delivery in a Pakistani clinical population.(29) This study is unique within the reviewed literature in simultaneously addressing all three target languages of this systematic review within a single evaluated platform. The digital platform's inclusion of regional dialect audio libraries — rather than relying solely on standardised dialectal variants of Urdu or Punjabi — is a methodologically significant innovation, as it directly addresses the dialectal heterogeneity that characterises spoken communication across urban and rural populations in Pakistan. The study's CASP-rated High quality score (9 out of 10) provides confidence in the validity of these findings, with the principal limitation being the partial applicability of its adult aphasia patient data to the paediatric ASD and SCD population that is the primary focus of this review; the authors note a child subgroup within the broader patient cohort for whom positive compliance outcomes were documented.(29)

#### *Educational and Early Intervention Applications*

Two studies addressed educational and early intervention domains. Bhatti et al. evaluated a multimedia e-learning platform delivering Sindhi-language educational content to children in Sindhi-medium schools in Sindh province, Pakistan, using a quasi-experimental design with a contemporaneous control group (N = 40).(28) Children exposed to the Sindhi-language digital platform demonstrated significantly greater improvement on teacher-rated learning outcome measures compared to the control group receiving conventional instruction ( $p < 0.05$ ), and both children and teachers reported higher engagement with the native Sindhi-language content relative to Urdu or English medium instruction. While Bhatti et al. did not recruit a population with confirmed ASD or SCD diagnoses, the study's educational findings are directly relevant to the review's broader objective of establishing the feasibility and effectiveness of Sindhi-language digital learning tools for children — a population that substantially overlaps with the communication and literacy needs of children with ASD enrolled in Sindhi-medium schools in the province.(28) Yasir's smartphone-based early intervention framework prototype received positive expert feasibility ratings (N = 15 specialist reviewers) and demonstrated that Urdu-language interface design significantly improved caregiver engagement with the framework compared to English-only prototypes tested in earlier pilot iterations.(27) However, the absence of child-level evaluation and the prototype-only status of the reported work mean that the framework's contribution to this review is limited to design feasibility rather than clinical evidence of efficacy.

#### *Outcome Measures and Measurement Instruments*

Substantial heterogeneity was observed in the outcome measures and measurement instruments employed across the seven core studies, precluding any quantitative pooling of results and reinforcing the appropriateness of the narrative synthesis approach. Table 4 presents a cross-study comparison of

primary outcomes, instruments, and key findings, organised to facilitate qualitative direction-of-effect comparison across studies using comparable outcome domains.

**Table 4. Outcome Measures and Reported Findings — Seven Core Studies**

Study	Primary Outcome(s)	Measurement Instrument	Reported Finding	Communication-Specific Outcome	Key Methodological Note
<b>Ahmad &amp; Shahid (2015)</b>	Usability rating (therapist & parent)	Questionnaire (non-standardised)	Positive	Not measured	No control; N not specified
<b>Ahmad et al. (2017)</b>	AAC use; therapist usability	Observational + expert rating	Positive	Not reported	Small pilot; limited independence
<b>Bhatti et al. (2020)</b>	Learning outcomes (pre-post)	Standardised test (teacher-rated)	Significant improvement ( $p < 0.05$ )	n/a — educational	N=40; control group used
<b>Yasir (2018)</b>	Expert feasibility rating	Expert panel review (N=15)	Positive feasibility	Not measured	Prototype only; no child outcomes
<b>Hassan et al. (2025)</b>	Speech production accuracy; compliance	Standardised speech assessment	Measurable improvement; compliance ↑	Partial (children subgroup)	Most rigorous design; 2025 data
<b>Loizides et al. (2015)</b>	Usability (SUS + custom scale)	System Usability Scale (SUS)	High scores (all user groups)	Social interaction sub-outcomes	N=18; multilingual validated
<b>Soomro &amp; Soomro (2018)</b>	App usability; PECS localisation quality	Expert ASD specialist review	Positive localisation; usability high	Not measured	No child efficacy data

TTS = Text-to-Speech; PECS = Picture Exchange Communication System; SUS = System Usability Scale;  $p < 0.05$  = statistically significant result reported by original authors. 'Not measured' indicates the outcome domain was not assessed in the study.

Only two studies — Bhatti et al.(28) and Hassan et al.(29) — employed validated, standardised measurement instruments (teacher-rated standardised attainment tests and a standardised speech production assessment, respectively) and reported quantitative outcome data permitting comparison with a reference or control condition. The remaining five studies relied on researcher-developed questionnaires, expert panel review, or descriptive usability ratings that, while valuable for design validation, do not constitute evidence of clinical efficacy. No study reported follow-up data beyond the immediate post-intervention assessment period, and no study reported generalisation of communication skills from the application context to naturalistic communication settings — a critical evidence gap noted in parallel systematic reviews of AAC technology more broadly.(8,9) The absence of blinded outcome assessment was a common methodological limitation across studies in which researchers both developed and evaluated the application, introducing a potential source of performance and detection bias that was acknowledged in the quality appraisal but could not be formally corrected within the narrative synthesis.

### Evidence Gaps

The synthesis reveals four critical and interconnected evidence gaps that define the current state of the literature. First, Punjabi — despite being the primary mother tongue of the largest linguistic community in Pakistan — has no standalone peer-reviewed mobile application study for ASD or SCD children and appears in only a single study as one of three co-supported languages. Second, no randomised controlled trial or study with an active comparator condition has been conducted to evaluate the superiority of Urdu-, Punjabi-, or Sindhi-language applications over English-language equivalents for ASD or SCD outcomes in South Asian children. Third, no study has examined the long-term impact of mobile application use on communication development, language generalisation, or academic attainment in this population beyond immediate post-session assessment. Fourth, the integration of emerging technologies — including augmented reality, artificial intelligence-driven adaptive learning, and emotion recognition — has not been evaluated in any application developed specifically for Urdu-, Punjabi-, or Sindhi-speaking children with ASD, despite their demonstrated feasibility in other language contexts.(31,32,15) These gaps collectively define the most urgent priorities for the next generation of research in this field.

## DISCUSSION

### *Principal Findings in Relation to Review Objectives*

This systematic review provides the first comprehensive, PRISMA 2020-compliant synthesis of the evidence base pertaining to high-technology mobile applications designed for children with Autism Spectrum Disorder (ASD) and Social Communication Disorder (SCD) in Urdu, Punjabi, and Sindhi. From an initial yield of 847 database records, 28 studies met eligibility criteria, of which seven constituted the core evidence base most directly aligned with the review's primary focus on South Asian regional language application development. The principal finding is that while a nascent but growing body of literature documents Urdu-language mobile application development for ASD and SCD children in Pakistan, Punjabi remains entirely absent as a primary application language from the peer-reviewed evidence base, and Sindhi is represented by a single study that does not target a confirmed ASD population. Across all seven core studies, the direction of reported effect was uniformly positive; however, the strength and clinical interpretability of these findings varied substantially as a function of methodological quality, with only two studies achieving a quality tier sufficient to support cautious clinical inference rather than design feasibility conclusions alone.

### *Contextualisation Within Existing Literature*

The finding that high-technology AAC and mobile communication interventions for ASD produce positive outcomes across diverse implementation contexts is consistent with the broader comparative evidence base. Ganz et al.'s meta-analysis reported a standardised mean difference of 1.24 for high-technology AAC on communication outcomes in individuals with intellectual and developmental disabilities,(8) while Moon et al. synthesised 19 trials and reported moderate to large positive effects of mobile application interventions on social, communicative, and adaptive behaviour in children with ASD.(9) The uniformly positive directional findings of the present review's core studies are therefore consistent with this global evidence trend; however, the present review advances the literature by demonstrating that this positive directionality extends — at least at the level of usability and feasibility evidence — to Urdu-language applications in Pakistani settings, a context that prior reviews had not examined. Equally, the review corroborates the widely acknowledged finding that the preponderance of mobile ASD intervention research originates from high-income, Anglophone settings and has not been systematically replicated in South Asian linguistic and cultural contexts,(16,17) a gap that previous narrative summaries have noted but not formally quantified with respect to the specific languages of Urdu, Punjabi, and Sindhi.

The Arabic-language application literature provides the most instructive regional comparator. Zibin et al. demonstrated statistically significant improvements in content question comprehension in children with ASD using an Arabic assistive application,(21) and several Saudi and Emirati studies have achieved structured usability validation of Arabic AAC tools with established instruments.(19,20,22,23) The Arabic evidence base, while itself modest in absolute terms, is more methodologically mature than the Urdu-Punjabi-Sindhi literature: it encompasses a higher proportion of studies employing validated outcome instruments, independent evaluators, and child-participant testing rather than expert-panel-only validation. This disparity highlights a developmental lag in the South Asian regional language literature that is not attributable to linguistic or technological barriers — since Urdu, Punjabi, and Sindhi are grammatically well-described languages with established script systems and digital encoding standards — but rather to the underinvestment in ASD research infrastructure and assistive technology development in Pakistan and the broader South Asian region.(35,36)

### *The Punjabi Gap: A Critical and Actionable Evidence Asymmetry*

The complete absence of Punjabi-specific mobile ASD or SCD application research from the peer-reviewed literature is the most clinically and policy-relevant finding of this review, and warrants explicit, extended discussion. Punjabi is the primary mother tongue of an estimated 60 to 90 million speakers in

Pakistan's Punjab province — the country's most populous — and is additionally spoken by substantial diaspora communities in the United Kingdom, Canada, and the Gulf region. The evidence that language-matched interventions produce superior communication outcomes is well-established in the general speech-language therapy literature,(43,44) and the AAC literature specifically has documented that children with ASD demonstrate faster symbol acquisition, greater generalisation of communication skills, and higher engagement rates when AAC systems are implemented in their primary home language rather than a second or school language.(45,48) In Pakistani clinical practice, children from Punjabi-speaking households who receive ASD or SCD intervention are routinely assessed and treated using Urdu- or English-language materials by default — not because of demonstrated equivalence but because no validated Punjabi-language tools exist. This represents a structural inequity in access to appropriately matched intervention that the present review quantifies for the first time and that should inform national disability and inclusive education policy in Pakistan.(35,36)

#### *Methodological Quality and Certainty of Evidence*

A critical appraisal of the seven core studies reveals a bifurcated quality landscape. The two highest-quality studies — Hassan et al.(29) and Loizides et al.(18) — provide evidence of sufficient methodological rigour to support tentative clinical and design recommendations, though with important caveats regarding population specificity (Hassan et al. primarily studied adults with aphasia) and linguistic transferability (Loizides et al. did not include any South Asian language). The five remaining studies fall into the Moderate or Moderate–Low quality tier and are more appropriately characterised as proof-of-concept or design validation contributions than as efficacy evidence. This quality distribution is not unexpected given the early developmental stage of this literature; development and usability studies necessarily precede clinical efficacy trials, and the studies by Ahmad and Shahid,(24) Ahmad et al.,(25) and Soomro and Soomro(26) represent essential groundwork without which larger-scale trials would lack an evidence-based application design to test. However, the absence of any randomised or quasi-randomised study comparing the efficacy of a Urdu-, Punjabi-, or Sindhi-language mobile application to a control or comparator condition means that the evidence base cannot yet support formal practice recommendations or clinical guidelines, and findings should be interpreted accordingly.

A specific and important methodological concern across multiple included studies is the co-occurrence of application development and application evaluation by the same research team without independent outcome assessment. This introduces performance and detection bias that inflates usability and satisfaction ratings, a limitation that is endemic to early-stage technology development research more broadly(46) and that underscores the need for independent third-party evaluation in future Urdu, Punjabi, and Sindhi application studies. The SWiM framework employed for narrative synthesis in this review explicitly accommodates the absence of quantitative pooling where study heterogeneity and methodological variability preclude meta-analysis,(42) and the direction-of-effect synthesis presented in Table 3 of the Results section is accordingly framed as exploratory rather than conclusive.

#### *Emerging Technologies and Future Directions*

The systematic review identifies a conspicuous absence of augmented reality (AR), artificial intelligence (AI)-driven adaptive learning, and natural language processing (NLP) features in any application developed specifically for Urdu-, Punjabi-, or Sindhi-speaking children with ASD. This contrasts with their established and growing incorporation into ASD applications in other language contexts: Hashim et al. demonstrated that an AR-enhanced vocabulary application produced superior word retention in children with mild autism compared to conventional formats,(31) Taufiq et al. piloted an AR rehabilitation app for ASD with positive engagement findings,(32) and Rehman et al. outlined a comprehensive post-COVID-19 framework for AI-enhanced ASD applications that prioritises personalised adaptive learning, remote delivery, and emotion recognition.(15) The participatory co-design methodology employed by Loizides et al. — which produced the highest-quality and most

generalisable application framework in this review — has also not been replicated in any South Asian regional language study, despite substantial evidence that co-design with children, caregivers, and therapists produces applications with significantly superior ecological validity, usability, and cultural appropriateness.(18,33) Future studies developing Punjabi- or Sindhi-language ASD applications should incorporate these methodological and technological advances from inception rather than retroactively, to avoid compounding the existing lag in evidence quality.

### *Clinical and Policy Implications*

The findings of this review carry three principal implications for clinical practice, application development, and national policy. First, clinicians and speech-language therapists practising in Pakistan should be aware that while Urdu-language mobile AAC tools exist and have received preliminary positive usability evaluations, none has been validated in a controlled efficacy trial, and their use should be accompanied by systematic ongoing outcome monitoring at the individual patient level using validated communication assessment instruments. Second, application developers and digital health researchers in South Asia are strongly encouraged to prioritise Punjabi-language application development as the most critical and underserved evidence gap identified by this review, and to pursue co-design methodologies and independent evaluation frameworks consistent with the highest-quality examples in the international literature, exemplified by Loizides et al.(18) Third, the Government of Pakistan's national disability policy framework and UNESCO's inclusive education guidelines both mandate culturally and linguistically appropriate educational support for children with disabilities;(35,36) the present review provides the first systematic evidence that this mandate is not currently being met with respect to Punjabi- and Sindhi-speaking children with ASD, and should be cited by policy advocates seeking to secure research funding and curriculum reform commitments in this domain.

### *Limitations of This Review*

Several limitations specific to this review's methods and evidence base must be acknowledged. First, the restriction of eligibility to English-language publications may have excluded relevant studies published in Urdu, Punjabi, Sindhi, or other regional languages — a pragmatic constraint that reflects the operational feasibility of independent dual review but that may systematically undercount locally published grey literature and conference proceedings not indexed in international databases. Second, the heterogeneity of study designs, populations, outcome measures, and application types across included studies precluded quantitative synthesis and necessitated narrative methods; the direction-of-effect findings reported in this review must therefore be interpreted as exploratory indicators rather than pooled estimates of efficacy. Third, the core evidence base of seven studies is small in absolute terms and reflects a nascent literature that is not yet sufficient to support formal clinical guidelines or GRADE-level evidence ratings. Fourth, several included studies did not report sufficient sample characteristic data — including age ranges, diagnostic instruments, or cognitive profiles — to assess population comparability across studies, limiting the depth of the cross-study synthesis. Fifth, the absence of PROSPERO registration prior to search commencement — a consequence of the emergent nature of this specific review topic — means that this review is at moderate risk of post-hoc decision-making bias, which the authors have sought to mitigate through prospective PICOS specification and transparent dual-reviewer screening documentation.

### *Priorities for Future Research*

Based on the evidence gaps identified in this review, five specific and actionable research priorities are proposed. First, there is an urgent need for the co-design and rigorous clinical evaluation of at least one Punjabi-language AAC mobile application for children with ASD or SCD in Pakistan, developed in partnership with Punjabi-speaking caregivers, speech-language therapists, and child participants, and evaluated using validated communication outcome instruments in a controlled design. Second, a randomised controlled trial comparing the efficacy of a Urdu-language mobile AAC application against

conventional Urdu speech-language therapy should be conducted with a target sample size calculated a priori and blinded outcome assessment. Third, longitudinal follow-up studies examining the durability of communication gains and the generalisation of mobile-supported skills to naturalistic daily communication settings are needed across all three target languages. Fourth, future application development studies should integrate AR and AI-driven adaptive features — given their demonstrated efficacy in other language contexts — and evaluate these technologies specifically in Urdu, Punjabi, and Sindhi through independent, pre-registered trials. Fifth, a collaborative research network between academic institutions in Pakistan, South Asian diaspora communities, and international assistive technology research groups should be established to accelerate the pace and quality of application development and evaluation in this underserved linguistic context, following models established in the Arabic-language ASD application literature.(19,21,22)

## CONCLUSION

This PRISMA 2020-compliant systematic review is the first to formally identify, characterise, and critically appraise the evidence on high-technology mobile applications for children with ASD and SCD in Urdu, Punjabi, and Sindhi. From 28 included studies, seven were identified as most directly aligned with the review's primary focus, collectively demonstrating that Urdu-language mobile AAC and speech applications are technically feasible and receive positive usability evaluations in Pakistani contexts, that Sindhi-language digital educational tools show significant efficacy in a controlled educational design, and that the only platform evaluated across all three target languages simultaneously demonstrated measurable clinical benefits. However, the review also reveals that Punjabi — the primary mother tongue of the most populous province in Pakistan — has produced no standalone peer-reviewed mobile ASD application study, and that no randomised controlled evidence exists for any Urdu-, Punjabi-, or Sindhi-language mobile intervention for ASD or SCD children. The overall certainty of the available evidence remains low to moderate owing to small sample sizes, absence of controlled designs, non-standardised outcome instruments, and researcher-led evaluation in the majority of included studies. These findings establish a clear evidence-based mandate for urgently prioritised, co-designed, and independently evaluated mobile application research in Punjabi and Sindhi, supported by national disability policy commitments and international inclusive education frameworks, to ensure that children with ASD and SCD in South Asia receive communication interventions that are genuinely matched to their linguistic and cultural identities.

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