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Systematic Review

Artificial Intelligence Assessment and Intervention for Psychological Loneliness in Children: A Systematic Review

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Abstract

Background: Childhood loneliness has emerged as a global public health challenge. Prolonged loneliness increases the risk of psychological disorders, whereas traditional assessment and intervention systems face structural limitations. Artificial intelligence (AI) technology, with its advantages of multimodal perception and personalized intervention, offers a promising new approach to the prevention and control of childhood loneliness. **Methods:** The study followed preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines, systematically searching the Web of Science, Scopus, and China national knowledge infrastructure (CNKI) core databases for literature from 2015 to 2025. Following screening, 76 studies were included. Topic clustering and mechanism deconstruction were applied to comprehensively review the current state of research in the field. **Results:** This field has shown a three-stage evolutionary trajectory characterized by nascent exploration, steady growth, and rapid development, forming four major research clusters. This study proposes an AI-based assessment system covering assessment goals, technical methods, data sources, and application scenarios, alongside an AI intervention framework encompassing intervention goals, technical platforms, intervention models, and effect verification. In addition, a three-dimensional application mechanism framework of assessment, intervention, and humanistic empowerment is introduced. **Conclusions:** The theoretical framework and practical mechanisms proposed in this study provide a scientific basis for the digital and intelligent transformation of children's mental health services, and contribute to the development of a more inclusive children's mental health support system. **Registration:** The study has been registered on https://www.crd.york.ac.uk/PROSPERO/ (registration number: CRD420261302115; registration link: https://www.crd.york.ac.uk/PROSPERO/view/CRD420261302115). The full review protocol is publicly available via the above PROSPERO webpage.

Keywords: artificial intelligence; children's sense of loneliness; assessment and intervention; mental health; systematic review

1. Introduction

Children's mental health is a key indicator of social well-being and a nation's future. Loneliness, as a universal psychological experience, is defined at its core as the subjective feeling that occurs when an individual's perceived social relationships differ significantly in quality or quantity from their expectations (Perlman and Peplau, 1981).

Although loneliness is often regarded as a negative emotional experience, it holds unique functional value from an adaptive perspective. Short-term loneliness can serve as an intrinsic psychological signal that motivates individuals to actively rebuild social connections and strengthen existing social relationships, thereby promoting the development of social adaptability (Cacioppo and Hawkley, 2009; Qualter et al., 2015). However, when loneliness is prolonged and intense, it can harm physical and mental health through neuroimmune mechanisms and increase the risk of psychological disorders such as depression and anxiety (Eccles et al., 2020). Notably, up to 80% of children and young adults experience loneliness at some point, and approximately 3% to 22% of individuals report long-term persistent loneliness (Hards et al., 2022).

Alleviating children's loneliness and providing sustained emotional support are therefore key to safeguarding children's mental health. Traditional assessment methods that rely on subjective reports and scarce professional intervention resources are difficult to meet the needs of large groups of children. Artificial intelligence (AI) technology, with its potential for multimodal perception, dynamic monitoring, and personalized intervention (Chen and Decary, 2020), offers a promising pathway toward building a more inclusive mental health support system for children. The value of this technology lies not only in alleviating the current sense of loneliness, but also in its great significance and social value to reduce the risk of mental illness in children in the future through early intervention.

At the same time, traditional systems for assessing and intervening in children's loneliness face multiple structural challenges. Regarding the assessment, existing methods rely heavily on subjective reports from teachers and parents or on children's self-reporting scales, making early identification, dynamic monitoring, and precise classification of loneliness difficult to achieve. As for the intervention, the scarcity and uneven distribution of professional psycholog-

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ical service resources make it difficult for traditional models such as group counseling and individual therapy to reach marginalized children and underdeveloped areas.

In addition, the rapid advancement of AI technology and the deep intersection with developmental psychology support the feasibility of this research. At the technical adaptation level, the synergistic development of multimodal perception technology, affective computing, and machine learning algorithms has made it possible to objectively assess loneliness based on non-verbal behavior data—such as facial expressions, vocal intonation, and body movements–as well as ecological data including social network interaction patterns and daily activity trajectories. At the level of intervention tools, the development of virtual companions, intelligent chatbots, and immersive virtual reality (VR) technology provides children with low-stress, personalized social training scenarios. These tools can simulate real social situations to help children enhance their social confidence and emotional regulation skills, as well as continuously optimize intervention strategies through algorithmic iterations to achieve dynamic adjustment of intervention outcomes.

Therefore, although systematic discussions on children's loneliness have been carried out globally, most existing research focuses on loneliness in older adults and related intervention studies. AI-based assessment and intervention practices based on the deep integration of technology and humanistic perspectives remain relatively scarce. At the same time, there is a general lack of systematic integration of theories from child developmental psychology with AI technology, and in-depth empirical analysis and theoretical explanation of the intrinsic mechanisms through which AI interventions act on children's loneliness remain insufficient.

Based on this, this study systematically proposes an AI-based assessment and intervention system for children's loneliness that integrates technology and humanistic care, with the aim of addressing this gap. By systematically reviewing the relevant theoretical mechanisms, technical approaches, and practical models, this study examines the integration of technological adaptation and humanistic care. The ultimate goal is to provide a theoretical basis and practical framework for a more scientific and inclusive children's mental health security system, promoting the digital and intelligent transformation and universal development of children's mental health services.

2. Research Theory

The impact of AI on children's psychological loneliness is an emerging interdisciplinary field. Therefore, this study reviews the academic history and theoretical foundations of this field and constructs a methodological framework for AI-based assessment and intervention of children's psychological loneliness across four dimensions: academic history review, core theoretical framework, concept definition, and research questions. This framework provides solid theoretical support and clear logical guidance for the subsequent systematic review.

2.1 Analysis of Related Academic Fields

With the advancement of the digital age, the prevalence, concealment, and harmful effects of children's loneliness have become more prominent, and the limitations of traditional assessment and intervention models have become increasingly apparent, prompting the academic community to explore innovative, technology-driven approaches. AI technology, with its unique advantages in multimodal perception, affective computing, and personalized interaction, offers novel possibilities for overcoming the bottlenecks of traditional methods and achieving precise assessment and efficient intervention for children's loneliness. Related research is gradually evolving from theoretical groundwork and technological exploration toward integrated system construction.

2.1.1 Theoretical Foundation Stage: Academic Groundwork for the Correlation Between Loneliness and Children's Mental Health

Early academic research systematically explored the core dimensions, influencing factors, and health effects of psychological loneliness in children, laying a solid theoretical foundation for the subsequent intervention of AI technology. In a broad sense, social isolation refers to the lack of social connections in terms of the size, diversity, or frequency of social networks (de Jong-Gierveld et al., 2018). The global implementation of disease control measures objectively limited the frequency and depth of children's family social interaction, a reality that has significantly increased both the probability and intensity of psychological loneliness among children (Serafini et al., 2020).

Empirical studies have confirmed that children's psychological loneliness is not an isolated psychological experience, but is closely associated with multidimensional health risks and problem behaviors. At the physical health level, it is significantly associated with adverse outcomes such as poor physical health and sleep disorders (Matthews et al., 2017); At the level of behavioral development, long-term or intense feelings of loneliness increase the risk of high-risk behaviors among adolescents such as smoking, substance abuse, and alcohol misuse. It poses a potential threat to physical and mental health as well as lifelong development (Stickley et al., 2014).

More crucially, scholars have identified associations between loneliness and children's mental health. Research has found significant cross-sectional and prospective associations between loneliness and anxiety as well as depression in children with neurodevelopmental disorders, including social phobia, anxiety, depression, and autism spectrum disorder (ASD) (Hards et al., 2022). Other studies focusing on adolescents with ASD have further confirmed a positive correlation between loneliness and the severity of so-

cial anxiety symptoms (White and Roberson-Nay, 2009). At the same time, the limitations of traditional assessment and intervention models have become increasingly apparent, as existing assessments are highly dependent on self-reporting and subjective evaluation (Kraemer et al., 2003). These real-world challenges provide a clear academic entry point for the application of AI technology.

2.1.2 Technical Exploration Stage: Initial Practice of Digital Intervention and Exploration of AI Adaptation Potential

With the advancement of digital technology, the academic community began to introduce digital tools into the intervention of children's loneliness, accumulating practical experience for the deeper application of AI technology. Research at this stage focused on verifying the feasibility of digital intervention tools, resulting in a number of representative exploratory achievements.

One study developed a smartphone application for loneliness in young people, +Connect, which significantly reduced participants' loneliness scores over six weeks of digital intervention, with effects remaining stable at a three-month follow-up (Lim et al., 2019). A separate study introduced G4H, a 5-module computerized social identity intervention that effectively reduced loneliness through group relationship-building and maintenance training (Haslam et al., 2016).

Regarding assessment techniques, although a mature AI-based assessment system had not yet been established, some studies began to explore the value of multi-source data. Secondary analysis revealed that children's self-reported loneliness could predict parents' and teachers' assessment of their social anxiety and depression symptoms, providing ideas for subsequent multimodal data integration (Alfano et al., 2009). In addition, the effectiveness of remote intervention models was verified. Studies confirmed that remotely delivered psychological interventions produced therapeutic effect comparable to those of face-to-face interventions, laying the groundwork for the large-scale promotion of AI-based interventions (Nelson and Patton, 2016).

2.1.3 Development Bottleneck Stage: Insufficient Integration of Technology and Humanities and Lack of Mechanism Exploration

Although initial progress has been made in AI-based assessment and intervention on children's loneliness, the field remains at a development bottleneck stage, with core limitations concentrated in three aspects: insufficient theoretical integration, shallow mechanism exploration, and lack of adaptive design.

Firstly, at the theoretical level, existing technological applications tend to be technology-centered and lack systematic integration of theoretical frameworks from child development psychology. Secondly, in terms of assessment mechanisms, standardized AI-based assessment models based on multimodal data have not yet been established. Existing research still relies on single-source self-reported measures and is vulnerable to negative emotional bias and common method variance (Sharma et al., 2009), with limited technical interpretations of the two-way interaction mechanisms between loneliness and mental health.

Finally, regarding intervention mechanisms, in-depth empirical analysis of the action pathways of core AI technologies, such as virtual interaction and personalized recommendation, remains lacking. Existing intervention studies are mostly small-sample pilots and mostly focus on populations with social anxiety, and their applicability to other common mental health problems, such as depression, has not been clearly established.

At the same time, ethical standards and privacy protection frameworks remain incomplete, and concerns of data security and algorithmic transparency have become important factors restricting the deeper application of AI technology. These bottlenecks collectively point to the core developmental direction of the integration of technology and humanistic principles, laying the foundation for subsequent academic research.

2.2 Theoretical Framework

The assessment and intervention of children's psychological loneliness is a multidisciplinary research topic that requires adherence to the principles of children's physical and mental development and systematic exploration informed by the logic of technology application. Theories drawn from developmental psychology, educational constructivism, behaviorism, neuroscience, and the philosophy of technology provide a theoretical reference for the research design and optimization of assessment and intervention, and also establish the theoretical analytical framework for subsequent research on AI-based intervention in this field.

Cognitive Development Theory: Piaget's theory of cognitive development divides children's cognitive development into four stages: sensorimotor, preoperational, concrete computation, and formal computation. Children at different stages exhibit significant differences in thinking patterns and information processing abilities (Piaget, 1964). At the assessment level, AI algorithms' interpretation of children's social behavior must be referenced to the typical cognitive abilities of their corresponding age group. At the intervention level, the complexity, abstraction, and task instructions of AI interactions must be matched to the child's concrete operational or formal operational stage.

Constructivist Theory: Constructivist theory emphasizes that learning is a process in which individuals actively construct knowledge and experience. Its core elements include situational learning and scaffolding support (Hein, 1991). Accordingly, AI should not merely provide predetermined answers or training, but should create open, realistic, and explorable virtual social contexts that inspire chil-

dren to initiate interactions. At the same time, AI should act as an intelligent scaffold, providing appropriate support when children encounter social difficulties through dynamic prompts and progressive questioning, and gradually removing it as their abilities improve, ultimately promoting their social confidence and autonomous internalization of skills.

Behaviorism Theory: Behaviorist theory, centered on reinforcement and feedback, holds that positive behavioral reinforcement and timely feedback promote individual behavioral change (Staddon, 2021). AI technology can surpass human interveners to achieve hyper-personalized, immediate and consistent reinforcement. By precisely identifying target social behaviors, AI can provide immediate positive feedback. This high-frequency, delay-free reinforcement mechanism can effectively increase the likelihood of adaptive behavior, helping children with a strong sense of loneliness to establish positive social behavior patterns and break the cycle of maladaptive responses.

Neuroscience Theory: Neuroscience theory focuses on the connections between brain structure, neural mechanisms, and cognitive function, providing a physiological basis for AI-based assessment of loneliness in children (Barbey, 2018). Studies have shown that long-term loneliness affects brain activity and neural connection patterns in children, and AI can more accurately identify loneliness-associated changes in neural and cognitive functions by integrating physiological signals with behavioral data. At the intervention level, AI tools based on the principle of neural plasticity can be designed to target social training tasks that promote positive development of relevant brain regions in children, thereby alleviating the effects of loneliness at the neural mechanism level.

Phenomenology of Technology: Technology phenomenology focuses on the interaction between technology, the individual and the environment, and holds that the effectiveness of technology tools depends on their fit with individual needs and environmental characteristics. For children's psychological loneliness, its emergence and alleviation are deeply embedded in the diverse ecosystem of family, school, and peer relationships. Therefore, AI-based assessment and intervention should have ecological validity. The assessment data should be drawn from natural settings as much as possible, rather than from laboratory environments alone, and interventions should be integrated into children's daily routines.

The five theories outlined above collectively provide multiple theoretical perspectives and research analytical dimensions for research on AI-based assessment and intervention of children's psychological loneliness from the dimensions of developmental principles, intervention logic, physiological mechanisms, and technological adaptation. Subsequently, this study will strictly follow systematic review methodology to comprehensively synthesize the empirical research evidence in this field. Based on the evidence-based comprehensive results, the above theories will be integrated and refined to construct a theoretical analytical framework consistent with the empirical findings, achieving an organic connection between theoretical guidance and empirical research, and providing a rigorous and practice-oriented research paradigm for this field.

2.3 Research Concept Definition and Research Questions

Based on a comprehensive analysis of the relevant academic history and theoretical basis, and informed by the evolution of the field, this study defines and proposes the concept and theoretical structure of AI-based assessment and intervention in children's psychological loneliness. Specifically, it encompasses four core conceptual elements that are both relatively independent and interrelated, together forming a complete theoretical system.

First, the multidimensional evaluation dimension of children's psychological loneliness, involves constructing a multidimensional framework grounded in children's cognitive developmental stage and psychological characteristics, encompassing three dimensions: subjective experience, behavioral performance, and physiological associations. Among these, the subjective experience dimension emphasizes the difference between children's expectations for social relationships and their own perceived social relationships. The behavioral manifestation dimension includes observable behavioral performance characteristics such as social withdrawal and interaction frequency. The physiological association dimension is related to the emotional physiological signals of loneliness. This factor is the key component of AI-based assessment technology and defines the measurement system and logic of data acquisition of AI-based assessment models.

Second, the adaptive application system of AI technology refers to a hierarchical application system that integrates multimodal perception, intelligent interaction, machine learning, and related technologies, based on the principles of children's development. In the assessment stage, the objective identification of loneliness is achieved by relying on multimodal data fusion technology. In the intervention phase, virtual social scenarios tailored to children's cognitive levels are constructed through intelligent interaction technology. Concurrently, machine learning algorithms are used to personalize the matching of assessment results to intervention strategies. This element is the core carrier that connects technological tools with the children's needs and determines the scientific nature and feasibility of AI-based practices.

Third, the theory-integrated intervention logic chain refers to a closed-loop logic chain of assessment, intervention and feedback based on cognitive development theory, behaviorist theory, neuroscience theory, and related frameworks. Specifically, intervention tasks suitable for the childhood developmental stage are designed based on cognitive development theory; positive reinforcement of social behavior is achieved based on behaviorist theory; physio-

logical and cognitive effects of the intervention are monitored based on neuroscience theory; and dynamic feedback and strategy adjustment throughout the intervention process are enabled through AI technology. This element constitutes the theoretical guarantee of AI intervention effectiveness and determines the systematicity and efficacy of the intervention practice.

Lastly, the technology and humanistic ethical and practical norms are the technical application constrains and practical guidance standards established with children's rights as the core, including data privacy protection, algorithmic transparency, and developmental fit of intervention. Among these, data privacy protection requires that AI tools should be restricted by ethical standards in the collection and use of children's data. Algorithmic transparency requires that the decision-making logic of evaluation and intervention should be explainable to an extent. Developmental fit requires that technical tools match the children's psychological development characteristics and avoid negative impact of technology on the real-world social skills of the child. This element represents the value orientation of AI practice and defines whether the research is humanistic and sustainable. Furthermore, the definition of a child adopted in this study follows that established by the Convention on the Rights of the Child, which defines a child as an individual below the age of 18 years, thereby providing an authoritative and concrete basis for delineating the scope of the research population (Assembly, 1989).

Therefore, this study defines AI-based assessment and intervention for children's psychological loneliness as a technical and practical system for the objective assessment, personalized intervention, and sustainable support of psychological loneliness in individuals under the age of 18. Built upon multidimensional assessment dimensions, adaptive AI technology systems, theory-integrated intervention logic chains, and techno-humanistic synergy norms, this study proposes a research framework integrating technology, theory, and ethics, laying the conceptual and logical foundation for subsequent empirical research and practical application.

Based on the academic history review, theoretical framework, and conceptual definitions outlined above, this study selected the Web of Science, Scopus, and China National Knowledge Infrastructure (CNKI) core databases to conduct a systematic review of relevant research from 2015 to 2025, comprehensively examining the basic overview, practical mechanisms, and thematic clustering of AI technology in the assessment and intervention of children's psychological loneliness from an integrated technology-humanistic perspective. This study aims to clarify the current state of research, core technical pathways, the internal logic and practical value, and to provide systematic references for academic advancement and practical application. As a result, five fundamental research questions (RQ) were formulated:

RQ1: What are the publication trends, country distributions, and research subjects of studies on AI-based assessment and intervention of children's loneliness?

RQ2: What are the research designs and assessment tools for AI-based assessment and intervention of children's loneliness?

RQ3: What are the relevant factors influencing children's psychological loneliness?

RQ4: How does AI technology assess and intervene in children's psychological loneliness, and what domains does it mainly cover?

RQ5: How can an application mechanism framework be proposed from the perspective of integrating technology and humanistic principles?

3. Materials and Methods

3.1 Literature Search

This study strictly adheres to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines for systematic reviews. The research protocol was registered in advance. Data extraction was carried out by two independent reviewers who cross-checked each other's work to ensure the accuracy and completeness of the extracted data.

To ensure the authorityand comprehensiveness of the literature search, the Web of Science, Scopus, and China national knowledge infrastructure (CNKI) databases were selected, covering multiple languages, with a search period from January 1, 2015 to December 31, 2025. Search keywords were applied in topic search mode, using the following terms: TS=(artificial intelligence) OR TS=(machine learning) OR TS=(deep learning) OR TS=(neural network) OR TS=(AI) OR TS=(chatbot) OR TS=(robot) OR TS=(human-computer interaction) OR TS=(social robot) OR TS=(social assistive robots) AND TS=(child) OR TS=(adolescent) OR TS=(teen) OR TS=(youth) OR TS=(pediatric) OR TS=(minors) OR TS=(nonage) OR TS=(under age) OR TS=(juvenile) AND TS=(alone) OR TS=(lonely) OR TS=(loneliness) OR TS=(solitary) OR TS=(isolated).

During the search process, non-research literature such as conference abstracts, book reviews, and editorials were excluded, and only peer-reviewed original research articles were included to ensure the academic rigor and research value of the included literature, laying a solid foundation for subsequent literature screening and data analysis.

3.2 Literature Screening Criteria

To ensure the accuracy and validity of the literature analysis, two authors collaboratively developed literature screening criteria based on the characteristics of the research topic, study population, methods, and content. The complete research literature screening process is illustrated in Fig. 1.

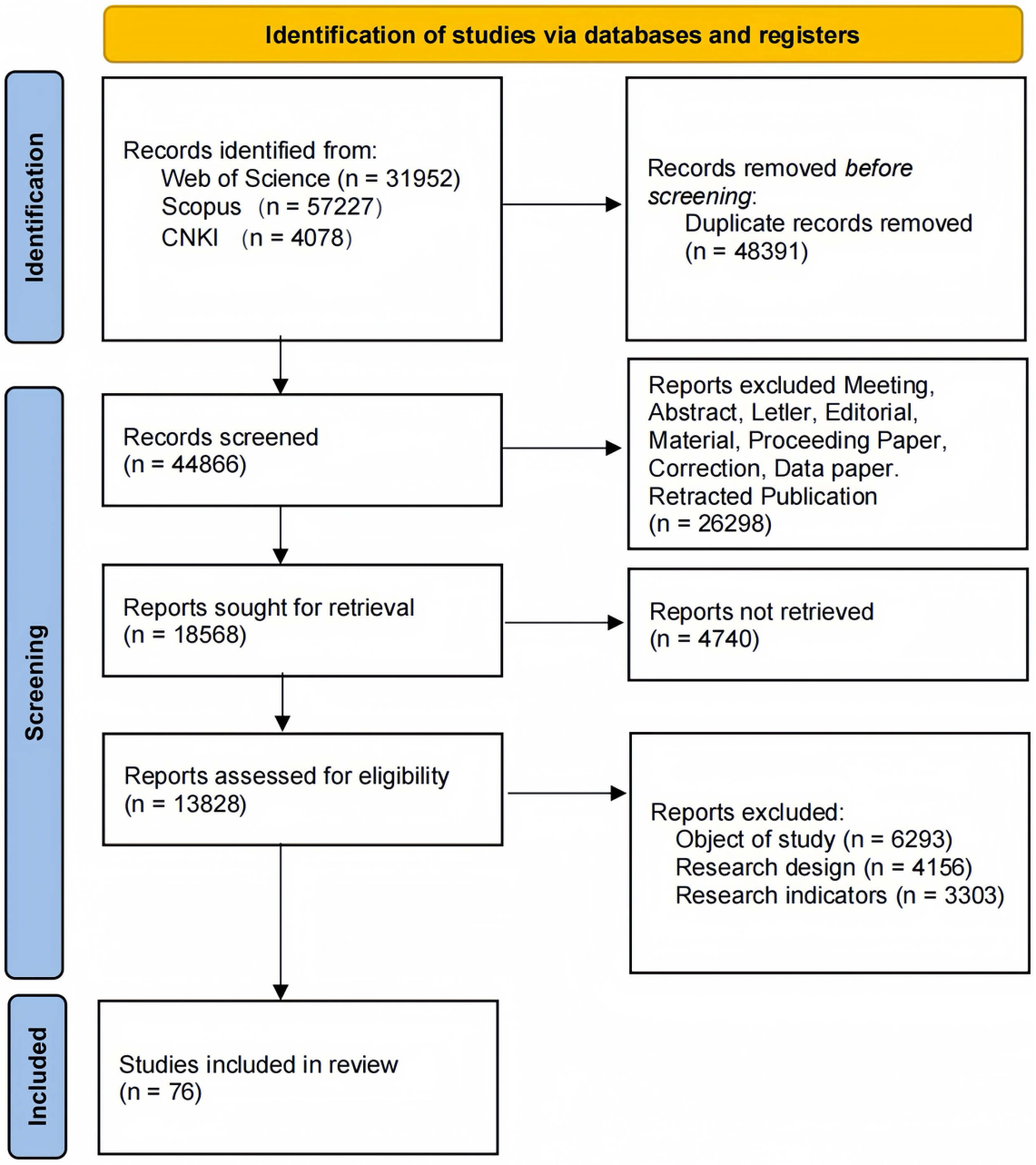


Fig. 1. PRISMA flow diagram of the literature selection process. PRISMA, preferred reporting items for systematic reviews and meta-analyses.

This study has established the following inclusion and exclusion criteria for literature. Special children groups are precisely defined and subdivided, with clear classification for each group. Left-behind children are classified based on the long-term absence of one or both parents due to work-related migration, leaving the children to reside in their registered residence. Migrant children are classified based on residing with their working parents in a location other than their registered residence. Disabled children are classified according to national disability assessment standards, covering various types of disabilities, including visual, hearing, speech, physical, and intellectual disabilities. Based on these criteria, the literature is screened to ensure precise stratified and categorized analysis in subsequent research, thereby enhancing the accuracy and relevance of the research findings.

Inclusion criteria for the literature were as follows: (1) The research participants were minors under the age of 18, focusing on the psychological loneliness, encompassing both typically developing children and adolescents as well as special pediatric populations, including left-behind children, migrant children, and disabled children; (2) The study addressed the direct application of AI technology in the assessment or intervention of psychological loneliness in chil-

dren, clearly distinguishing between core and auxiliary AI applications, prioritizing studies related to core AI technology and covering key content such as technical principles, implementation paths, or effect analyses; (3) The literature is an empirical study with clearly defined research methodology, data sources, and analytical logic; and (4) The study explicitly reported specific details of AI technology application, or contained extractable effect data, practical mechanisms, and other key information.

Exclusion criteria for the literature were as follows: (1) Study participants were adults, college students, or populations not clearly limited to children and adolescents, or studies did not distinguish between typically developing and special children groups; (2) Only generally mention "AI" and "children's mental health", without establishing a direct connection between AI technology and the assessment or intervention of psychological loneliness in children, or only use AI as a conventional digital tool for simple data analysis without core technology application; (3) The publication type comprised book reviews, editorials, conference abstracts, and other non-research texts, or articles that are solely theoretical speculation without empirical support; (4) The study did not provide specific AI technology application methods or intervention details, or lacked valid data to support its conclusions; and (5) The literature did not clearly define whether the research subjects belonged to special children groups, or did not extract group classification information.

Firstly, the study conducted an initial screening of the 93,257 records obtained from the initial database search, including 31,952 records from the Web of Science, 57,227 records from Scopus, and 4078 records from the CNKI. Prior to formal screening, the records underwent preprocessing, including removing 48,391 duplicate records. Following deduplication and pre-exclusion, a total of 44,866 valid records were retained for formal screening. Secondly, non-research publications were excluded, including conference abstracts, letters, editorials, editorial notes, progress reports, errata, data papers, and retracted articles, totaling 26,298 records and leaving 18,568 records for further screening. Thirdly, 4740 records were excluded due to unavailability of the full report, leaving 13,828 valid records. Subsequently, the study ensured consistency and accuracy of the screening results through a strict double-check process, further enhancing the reliability of the included literature. The entire screening process adhered to the pre-established inclusion and exclusion criteria, with careful review of the abstract, method, and core conclusions of each initially screened record. As such, the screening was further narrowed to the core research outcomes of AI-based intervention and assessment of psychological loneliness in children, with the pre-established exclusion criteria applied sequentially at each. A total of 6293 records were excluded due to non-compliance with participant criteria, 4156 due to non-compliance with study design requirements, and 3303 due to non-compliance with outcome indicators. Finally, 76 records that met all inclusion criteria were selected as the core analysis materials for this study. All included literature was evaluated for research quality and academic value.

Through the application of the above inclusion and exclusion criteria, the screening process effectively focused on core research results in the field of AI-based assessment and intervention of psychological loneliness in children, ensuring the academic quality and thematic relevance of the included literature and providing precise literature samples for subsequent analysis of research context sorting and practical mechanisms.

3.3 Results of Literature Quality Assessment

This study employed the Joanna Briggs Institute (JBI) 2024 version of the critical appraisal tool. The quality assessment of the 76 included articles was independently conducted by two reviewers, who evaluated the full text quality of each study. In cases of disagreement between the two reviewers, a third researcher with relevant expertise was consulted. Ultimately, a consensus was reached through joint discussion to resolve any differences.

As shown in Table 1, the overall methodological quality of the included literature was predominantly moderate to high, with high-quality studies accounting for 53.95% (n = 41) and moderate-quality studies comprising an additional 43.42% (n = 33). Collectively, these two categories constituted 97.37% of the total evidence base. Only two studies (2.63%) were rated as low quality. Importantly, neither of these studies exhibited fatal methodological flaws; their lower scores were attributable to minor deficiencies on a limited number of individual JBI appraisal items, with overall scores remaining close to the moderate-quality threshold. Retaining these studies in the final synthesis was deemed not only acceptable but methodologically preferable: their inclusion does not constitute a limitation of the review; rather, it underscores the comprehensiveness of the literature search and the transparency of the appraisal process. A sensitivity analysis excluding these two studies was subsequently conducted and did not materially alter the direction or magnitude of the pooled effect estimates, thereby reinforcing the robustness of the review's findings.

Table 1. Quality distribution of included literature.

Literature quality	Number of articles	Proportion
High quality	41	53.95%
Moderate quality	33	43.42%
Low quality	2	2.63%

Methodological quality varied significantly across research design types. The 11 randomized controlled trials (RCTs) demonstrated the highest overall quality, but their primary methodological limitations included the difficulty of blinding implementers to AI-based intervention measures and the absence of pre-registration in some stud-

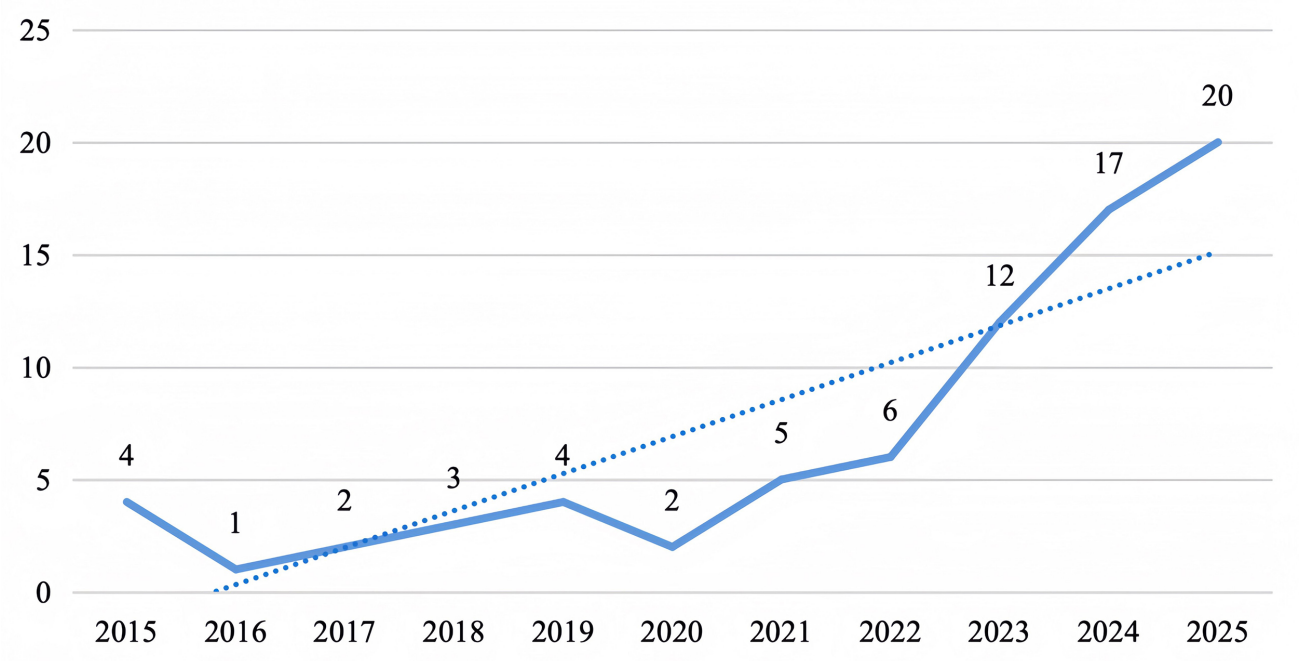


Fig. 2. Analysis of publication volume trends.

ies. The quality of the 23 quasi-experimental studies varied, with the core limitation being insufficient control of confounding factors in the baseline data between groups. The 32 cross-sectional studies were mainly of moderate quality, with the most common limitation being the risk of sample representativeness bias due to the convenience sampling strategy. The 10 qualitative studies generally exhibited insufficient methodological reporting, with half failing to clearly explain the philosophical stance of the research or to address researcher reflexivity.

In summary, the overall risk of bias in the included studies was evaluated as moderate, with the main sources of bias concentrated in selection bias and measurement bias. Despite the aforementioned methodological heterogeneity, the included literature provides valuable empirical evidence in their respective domains, and their overall quality is considered sufficiently reliable to support subsequent evidence integration and conclusion derivation.

4. Results

4.1 Trends in Publication Volume

Trends in the number of published articles can visually reflect the evolution of academic interest, research maturity, and development drivers in the field of AI-based assessment and intervention for psychological loneliness in children. As shown in Fig. 2, the distribution of publication volume over time allows the research in this field to be clearly divided into three distinct stages.

The first stage was the nascent exploration stage (2015–2019), during which the average annual number of published articles was relatively low and publication output remained minimal. The core nodes of the keyword temporal evolution map were sparse, with basic concepts such as "loneliness", "children", and "mental health" predominating, while keywords related to AI technology had not yet emerged as significant. This feature indicates that the field is still in the early exploratory stages of interdisciplinary integration, with academic research focused on fundamental issues such as the limitations of traditional assessment methods for children's psychological loneliness, the mental health implications of loneliness, and the preliminary exploration of AI technology's potential in the broader field of mental health. However, no specialized research focus on AI technology and children's loneliness had yet emerged. The alignment between technology and the core research topic remained limited, and academic consensus had not yet begun to form.

The second stage was the steady growth phase (2020–2022), during which the number of published articles increased substantially. Among them, technology-oriented keywords such as "machine learning", "social assistive robots", and "intervention" began to emerge and formed an initial network of associations with research subject keywords and associated health outcome terms. This co-evolution confirms the core transformation of the field. With the gradual maturation of multimodal perception and affective computing technologies as well as the emergence of the global prevalence of children's psychological loneliness, research shifted from basic conceptual exploration toward empirical validation of technical applications, focusing on specific directions such as the development of AI-based intervention tools and the exploration of multi-source data evaluation approaches. The alignment between technology application and core research topics significantly in-

creased, and academic attention entered a continuous upward trajectory.

The third stage was the rapid development stage (2023–2025), during which publication output grew exponentially, with 20 articles published in 2025 alone. The density of core technology keywords such as "artificial intelligence", "virtual reality", and "neural network" increased significantly. This pattern indicates that the field has entered a systematic development stage. Research is no longer confined to the validation of individual technologies, but has expanded into a three-dimensional integration of technology, theory, and ethics, focusing on both the precise assessment and intervention of psychological loneliness in specific groups of children using AI and the ethical frameworks and humanistic adaptability governing technology application. The explosion in the publication output resonates with the multidimensional expansion of the topic, reflecting that the academic consensus in the field has gradually taken shape. It has become a research hotspot in the intersection of children's mental health and AI.

Finally, the concurrent technological maturation and the increase of social demand have promoted the expansion of in-depth and breadth of research topics. Moreover, the increasing thematic richness and focus of the field have attracted more academic interest, thereby promoting the continuous increase in the publication output. This mutually reinforcing trajectory not only confirms the timeliness of the research theme but also quantitatively and thematically supports the next-generation innovation directions centered on the deep integration of technology and humanities.

4.2 Geographic Distribution of Studies

Studies on AI-based intervention and assessment of children's psychological loneliness have been conducted in a large number of countries worldwide, encompassing multiple regions and forming a multi-regional, cross-cultural research pattern. Characteristic research directions have emerged across different countries, shaped by their respective technological foundation and public health demands. The overall research is still dominated by countries in which technological development and children's mental health infrastructures are increasingly contributing to the literature, reflecting a trend toward greater balance and diversification, with regional research efforts increasingly supplementing one another.

Among all of them, China ranks first in terms of publication frequency, with research covering a broad range of topics related to local pediatric populations. The United States ranks second, with a main focus on the clinical verification and adaptation of AI chatbots and social robots for special pediatric populations, with the emphasis on the combination of technology translation and community mental health services. They are the leaders of exploring novel technological approaches. Other countries, particularly in Europe, Asia, and Oceania, serve as significant contributors, collectively forming a global research network in this field.

Overall, research on AI-based intervention and assessment of children's psychological loneliness is highly concentrated in countries with substantial investment in technology and public health. Developed economies lead in technological innovation and clinical application, while developing economies focus on local epidemiological investigations and basic applications. This distribution not only reflects the supporting role of AI technology infrastructure and research resources in advancing children's mental health research but also indicates that future efforts should be made to strengthen international collaboration, promote the popularization of technology in resource-limited settings, and build a more balanced and inclusive global research system.

4.3 Characteristics of the Research Participants

The research participants across the included literature mainly focused on children and adolescents, with ages ranging from 3 to 18 years, and school-aged children and adolescents comprising the majority. This clearly demonstrates a focus on specific developmental stages. The majority of the studies targeted children from primary through middle school as the main observation subjects, while some extended to preschool children with special needs, consistent with the developmental pattern of heightened loneliness prevalence during school age and adolescence. Sample sizes varied significantly across studies, meeting the dual needs of epidemiological survey research and precise intervention validation, and overall, were well representative. As shown in Fig. 3, from the perspective of group characteristics and stratification, the research subjects could be classified into four categories, with notable structural differences in their compositional proportions.

Firstly, children with ASD were the largest subgroup, accounting for 42.11% of the total. As the core target population for AI-based intervention and assessment, this group is characterized by deficits in social communication, impairments in emotional and cognitive processing, stereotyped behaviors, and social avoidance. Assessment in this population focuses on social functioning, emotion recognition, joint attention, and behavioral adaptability, and often employs multimodal data collection and dynamic quantitative evaluation methods. Intervention goals in this population include improving social motivation, reducing feelings of loneliness, and enhancing social skills, with research focusing on the collaborative improvement mechanisms by which AI addresses social disorders and loneliness. The primary technical approaches include social robots, virtual reality/augmented reality (VR/AR) immersive situational training, computer vision-based behavioral analysis, and personalized intelligent intervention, relying on structured interaction, repetitive guidance, and positive reinforcement to achieve stepwise improvement in social skills.

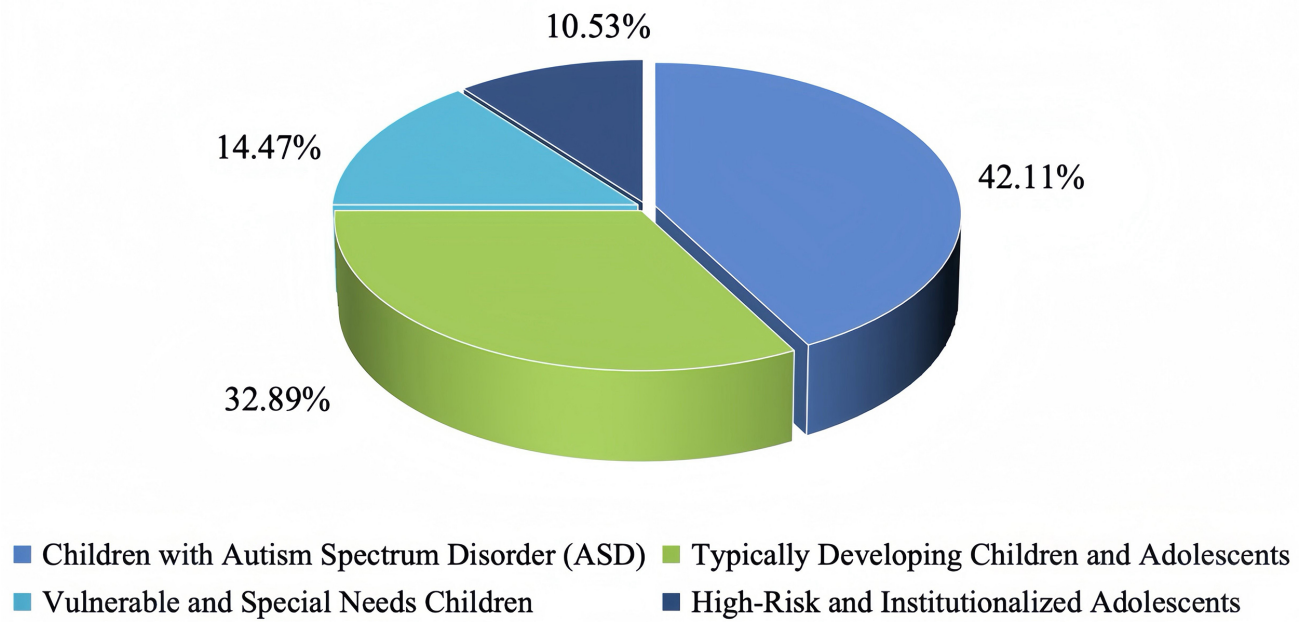


Fig. 3. Distribution of research populations. ASD, autism spectrum disorder.

Secondly, healthy children and adolescents account for 32.89% of the total. This group served as the main population for conducting community- and school-based epidemiological surveys and for exploring the impact factors of digital media use and loneliness. Research in this subgroup focused on loneliness levels, emotional states, digital media use patterns, peer relationships, and family environment, with large-scale screening, risk factor identification, and longitudinal tracking as the main methods. Intervention is mainly preventive in nature, emphasizing emotional regulation, social skill development, and the promotion of a healthy digital lifestyle. Research focus centered on the mechanisms underlying loneliness onset, influence pathways, and risk prediction models. Primary technical approaches include machine learning-based risk prediction, intelligent scale assessment, network psychometric analysis, and lightweight emotional companionship tools, serving the purposes of school-based mental health screening and early warning system.

Thirdly, disadvantaged and special needs children account for 14.47% of the total, including deaf children, children with learning disabilities, and refugee adolescents. This group is characterized by communication limitations, lack of social support, difficulties in social adaptation, and high risk of loneliness. Assessment in this subgroup emphasizes differentiated evaluation of communication ability, social support level, environmental adaptation, and emotional stress, with a particular focus on the cultural adaptability and equity of assessment tools. Interventions in this subgroup focus on compensatory support, emotional counseling, and social skills adaptation training, with research emphasis on the inclusiveness, accessibility, and specialized adaptation of AI technology. Primary technical approaches include simplified interaction, multi-sensory assistance, low-threshold intelligent tools, and cross-culturally adapted interventions, aimed at reducing the threshold for use and enhancing acceptability.

Finally, the fourth subgroup comprised high-risk and institutionalized adolescents, accounting for 10.53% of the total, including rural disadvantaged adolescents and institutionalized adolescents, who face challenges such as environmental isolation, resource scarcity, and inadequate psychological support. Assessment in this subgroup focuses on the severity of loneliness, comorbidity of depression and anxiety, social connection level, and environmental risk factors, emphasizing early identification and hierarchical risk. Interventions aim to alleviate psychological distress, rebuild social connections, and provide targeted psychological support, with research centered on the alternative and supplementary service value of AI in resource-limited settings. Main technical approaches include remote intelligent assessment, automated warning systems, lightweight chatbots, and community-based collaborative intervention platforms, enhancing service coverage and response efficiency.

Overall, the four subgroups form a clear stratification in terms of assessment orientation, intervention logic, and technology selection. Future research should prioritize group-specific designs, advancing AI technology from generalized toward precise, personalized, and scenario-based approaches, thereby enhancing the scientific rigor and effectiveness of loneliness intervention and assessment for children.

4.4 Research Design Distribution

The research designs of the included studies were mainly quantitative and empirical in nature, forming a di-

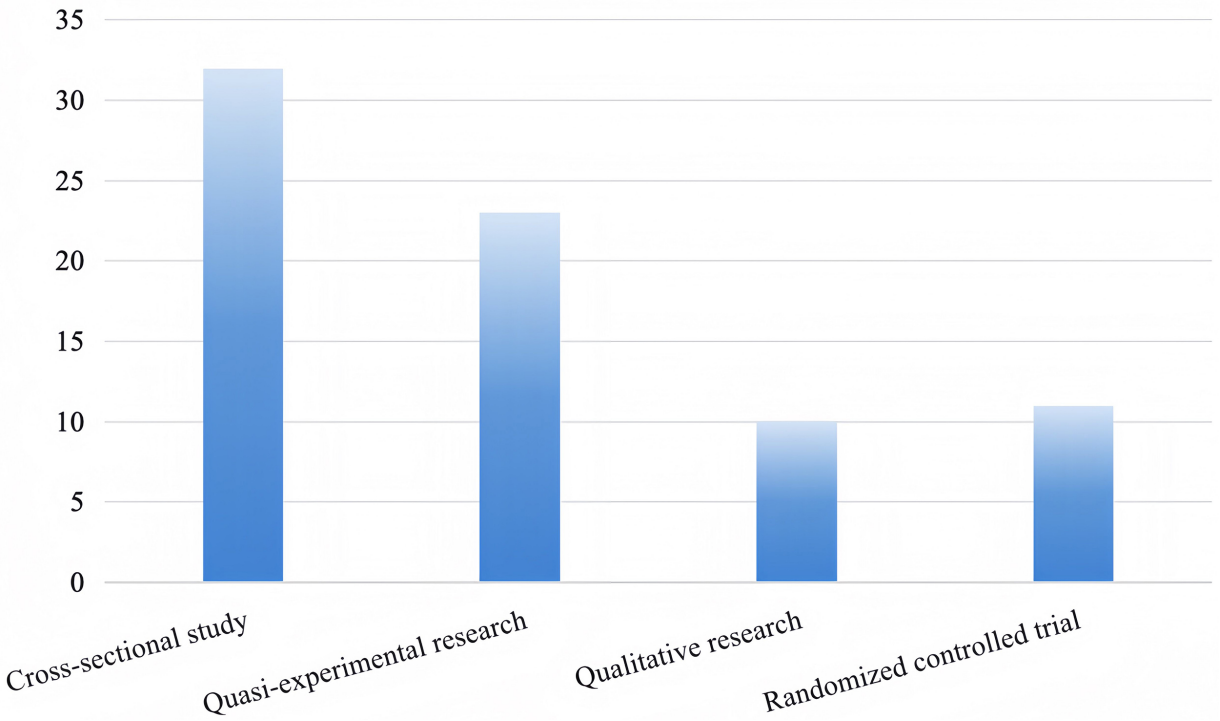


Fig. 4. Types of research design.

versified pattern based on cross-sectional surveys and the complemented by experimental interventions and intelligent modeling approaches. The research designs were closely aligned with the objectives of risk identification, mechanistic analysis of childhood loneliness, and AI technology application, reflecting both epidemiological characteristics and technology-oriented application, and providing clear methodological support for this field.

As shown in Fig. 4, cross-sectional studies accounted for the largest proportion of included research designs. They mainly employed questionnaires and psychometric network analysis to explore the associations between loneliness and factors such as digital addiction, social anxiety, family environment, and peer relationships. Sample sizes varied widely, covering both large-scale community surveys and studies focused on special groups in institutional settings. Quasi-experimental studies represented the second most common design ty, predominantly adopting non-randomized controlled and single-group pre-post designs to verify the effects of interventions such as social robots, AI chatbots, and VR. Behavioral observations and scale assessments were used to examine improvements in social functions and emotions. Qualitative research, through in-depth interviews and focus groups, explored the perspectives, experiences, and needs of children, parents, and healthcare professionals regarding AI-based interventions, supplementing subjective information that quantitative research cannot cover. Finally, RCTs, as the methodological gold standard for evaluating intervention effects, were used in the included studies to strictly validate the effectiveness and safety of AI-related interventions.

Overall, the distribution of research designs reflects a field in a stage of rapid development. In the future, efforts should prioritize longitudinal tracking, rigorous controlled designs, and the integration of multimodal data to enhance the quality of research evidence and provide reliable support for the standardized application of AI technology in the prevention and management of loneliness in children.

4.5 Loneliness Assessment Tool

Standardized assessment tools constitute the core foundation for achieving precise measurement, effect validation, and model construction. The assessment tools employed across the included literature consisted mainly of self-report and informant-report scales, supplemented by multiple methods such as behavioral observation, physiological indicators, and AI-based intelligent assessment, forming an integrated assessment system that combines traditional psychometric approaches with intelligent technology. These tools vary in reliability and validity, applicable age ranges, and assessment dimensions, jointly supporting the screening, diagnosis, risk prediction, and intervention effect evaluation of children's loneliness, as well as providing a standardized measurement basis for research in this field.

Currently, the most widely used tools in the included literature were traditional psychological scales, covering both single-dimensional and multidimensional formats, self-report and informant-report types, and populations ranging from typically developing children to children with ASD, children with special needs, and high-risk adolescents. The University of California, Los Angeles

(UCLA) Loneliness Scale, the most frequently used self-report tool, includes both short and full versions, is suitable for school-aged children and adolescents, and can quickly assess the level of loneliness. It has been widely adopted in cross-sectional surveys, network analysis, and machine learning-based prediction studies. The De Jong Gierveld Loneliness Scale focuses on distinguishing between emotional loneliness and social loneliness and is often used in cross-cultural and developmental studies, allowing for a more detailed analysis of the structure of loneliness. Some studies use the Children's Loneliness Scale (CLS), which focuses on school-based peer relationships and social deprivation experiences, and is suitable for primary school-aged students. For special populations such as children with ASD, research often combined tools such as the Social Responsiveness Scale and the Childhood Autism Rating Scale, incorporating loneliness as a secondary indicator of social impairment within a comprehensive assessment framework. Additionally, some studies adopted single-item direct measurement methods. This approach enables rapid data collection with simple items and is suitable for large-scale epidemiological surveys.

With the increasing integration of AI technology, intelligent assessment models are gradually becoming a new trend, promoting the assessment of loneliness from reliance on subjective scales toward objective, dynamic, and multimodal approaches. In machine learning and explainable AI research, scale scores are often used as outcome label variables, combined with demographic, family-related, behavioral, and social environment features to build predictive models capable of automatically identifying individuals at high risk of loneliness. Social robots, VR systems, and human-computer interaction platforms use objective indicators such as behavioral tracking, facial expression recognition, voice analysis, and reaction time measurement to assist in the evaluation of loneliness and social motivation, thereby reducing the bias of subjective reports. Digital assessment platforms and intelligent screening tools rely on a three-tier screening model to achieve efficient integration between community-level initial screening, institutional re-screening, and clinical diagnosis, improving the early identification efficiency of loneliness and social impairment in children with special needs.

Nevertheless, several limitations remain. Most studies continue to rely on traditional scales, with relatively limited integration of objective indicators and physiological data. The reliability and validity of intelligent assessment tools are insufficient, and their degree of standardization needs improvement. Furthermore, there is a lack of assessment tools suitable for young children and those with severe developmental disorders. Future research should prioritize the integration of traditional scales with intelligent technology, develop multimodal, dynamic, and standardized assessment tools tailored to different groups, and improve AI-driven loneliness assessment systems to provide a rigorous scientific basis for precise intervention.

4.6 Core Types of AI Technology

As shown in Fig. 5, the AI technology framework for the intervention and assessment of psychological loneliness in children comprises distinct modules, each relying on unique algorithmic logic and technical features, precisely tailored to the demands of different scenarios.

The first category encompasses machine learning and intelligent modeling technologies, with core algorithms such as random forest, XGBoost, and deep learning neural networks. Relying on multi-source samples such as children's psychological scale data, behavioral observation records, and family environment information, these technologies enable precise prediction of loneliness risk levels, intelligent screening of high-risk individuals, and dynamic assessment of emotional states. This technology is well suited to handling high-dimensional and complex datasets, and is capable of uncovering the correlative mechanisms between childhood loneliness and potential variables such as digital addiction, anxiety, and family upbringing methods, thereby providing data-driven support for personalized intervention.

The second category encompasses social robot and multimodal interaction technologies, integrating capabilities such as speech recognition, computer vision, and natural language processing. Through anthropomorphic robot platforms and virtual interaction scenario simulations, these technologies build structured social interaction scenarios for children. Their core function lies in recreating realistic social situations, helping children experiencing loneliness to establish social motivation and enhance communication willingness. It is the core technical platform for emotional guidance and social skills training.

The third category comprises VR/AR immersive interaction technologies, relying on VR/AR technologies to construct digital social and life simulation scenarios, allowing children to receive intervention in a safe and controllable virtual environment. These technologies reduce psychological defensiveness through immersive experiences and are used to simulate social interactions, stress coping scenarios, and other contexts, assisting children in learning emotional regulation and social interaction skills through experiential practice. They serve as the core tools for scenario-based intervention.

The fourth category encompasses intelligent chatbot and natural language processing technologies, relying on large language models and affective computing algorithms to provide immediate emotional companionship and behavioral guidance through lightweight modalities such as text and voice interaction. Their primary advantage lies in their strong inclusiveness, covering typically developing children and rural disadvantaged youth groups. They are applied in daily psychological counseling, emotion monitoring, and popular science education, addressing the gap in psychological support in settings with low-intervention frequency scenarios.

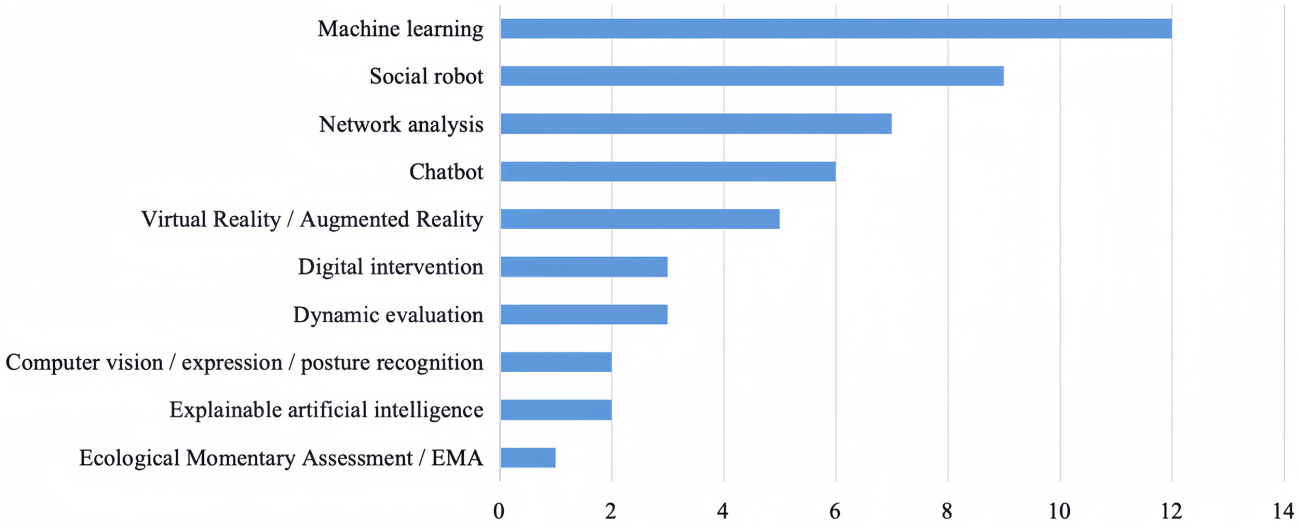


Fig. 5. Core AI technology types. EMA, ecological momentary assessment; AI, artificial intelligence.

4.7 Factors Related to Loneliness

The emergence and development of children's psychological loneliness are influenced by multiple factors operating at the individual, family, school, and digital environment levels. These factors interact to form a complex network of risk and protective mechanisms, which serves as an important basis for AI-based precise assessment and stratified intervention.

Firstly, at the individual level, psychological traits, emotional states, and behavioral problems are the core internal influencing factors of loneliness. Traits such as extraversion and emotional stability act as significant protective factors, significantly reducing loneliness levels, whereas social anxiety, depressive mood, low self-esteem, and difficulties in emotion regulation can intensify the experience of loneliness. Furthermore, problematic smartphone use, internet addiction, and excessive screen exposure are key behavioral risk factors. Moreover, children in special groups, such as those with ASD or hearing impairments, face a significantly higher risk of loneliness compared to typically developing children, attributable to inherent deficits in social communication.

Secondly, the family and school environments are crucial external contexts for the development of loneliness. At the family level, low socioeconomic status, poor parent-child relationships, parental emotional neglect, and excessive mobile phone use can all weaken children's sense of security and perceived social support, thereby increasing the risk of loneliness. At the school level, the quality of peer relationships plays a decisive role. Peer rejection, bullying, absence of friendships, and lack of peer acceptance are strong predictors of loneliness, whereas positive peer support can effectively buffer loneliness. Differences in school environments, the quality of teacher-student relationships, and availability of community resources also exert a significant impact on children's loneliness levels.

Finally, digital media and sociocultural factors constitute important contemporary triggers of loneliness in children. The impact of different types of digital media use on loneliness varies considerably: passive activities such as video watching, web browsing, and passive social media use can increase feelings of social isolation, whereas moderate gaming and purposeful online social interaction may alleviate loneliness. The information cocoons created by algorithmic recommendations, as well as cyberbullying and online victimization, further exacerbate psychological alienation.

Overall, childhood loneliness is the result of complex interactions among internal traits, family upbringing, school socialization, and the digital ecosystem. Clarifying these influencing factors provides a scientific basis for AI technology to achieve risk identification, precise assessment, and personalized intervention.

4.8 Research Topics on AI-Based Assessment and Intervention of Psychological Loneliness in Children

To further examine the research hotspots of AI technology in the assessment and intervention of psychological loneliness in children, this study systematically reviewed 76 articles spanning the period from 2015 to 2025 and constructed key topic summary tables, as shown in Tables 2,3. The thematic classification and specific categories were formulated on the basis of inductive synthesis and analytical extraction from the full texts and empirical data of the 76 included studies. Four major research topics and their corresponding subcategories pertaining to AI-based assessment and intervention of psychological loneliness in children were identified. Through systematic analysis of these research topics, the research focuses of different scholars were clearly delineated, and similarities and differences in research perspectives within the field were clarified.

Table 2. Research literature on AI-based assessment of psychological loneliness in children.

Topics	Specific categories	Partial references
Evaluate objectives	Loneliness prediction	(Zasso et al., 2025)
	Assessment of special group characteristics	(Zasso et al., 2025)
Technical approach	Machine learning	(Qin et al., 2024)
	Network analysis	(Zhang et al., 2025)
	Ecological momentary assessment (EMA)	(Xiao et al., 2024)
	Structural equation model (SEM)	(Xie et al., 2022)
	Explainable AI methods	(Zasso et al., 2025)
Data source	Questionnaire survey data	(Gao et al., 2016)
	Objective sensing data	(Weibel et al., 2020)
	Electronic health records and clinical data	(Sharma et al., 2025)
	Biological sample data	(Zhang et al., 2023)
	Social media data	(Touloupis, 2024)
Applicable scenarios	Clinical scenarios	(Kabacińska et al., 2025)
	Campus scene	(Zhang et al., 2024)
	Community/family scenarios	(Fu et al., 2020)
	Digital and Intelligent Environment	(Fox et al., 2024)

AI, artificial intelligence.

Table 3. Thematic summary of research literature on AI-based intervention for children's psychological loneliness.

Topics	Specific categories	Partial references
Intervention objectives	Relief of loneliness	(Zasso et al., 2025; Zhang et al., 2024)
	Improving social skills	(Lim et al., 2019)
	Reduce the risk of mental illness	(Meier et al., 2025)
	Improvement of digital intelligence literacy	(Xie et al., 2022)
Technology carrier	Smartphone application (APP)	(Lim et al., 2020)
	Social robots	(Kabacińska et al., 2025; Weibel et al., 2020)
	Chatbot	(Escobar-Viera et al., 2023)
	Web Platform	(Todorovic et al., 2025; Wagner et al., 2022)
	Virtual reality (VR/AR)	(Kaboski et al., 2015)
Intervention mode	Cognitive Behavioral Intervention (CBI)	(Riddleston et al., 2023)
	Positive Psychology Interventions	(Fox et al., 2024; Lim et al., 2019)
	Peer support intervention	(Todorovic et al., 2025)
	Family participatory intervention	(Pine et al., 2024)
	Personalized adaptive interventions	(Hennessey et al., 2021)
	Multimodal integration interventions	(Escobar-Viera et al., 2023)
Effect validation	Quantitative evaluation metrics	(Weibel et al., 2020)
	Qualitative feedback analysis	(Kabacińska et al., 2025; Kelly et al., 2018)
	Long-term follow-up	(Hennessey et al., 2021)
	Control experiment	(Hennessey et al., 2021)

VR/AR, virtual reality/augmented reality.

4.8.1 Research Topic Focus: AI-Based Assessment of Psychological Loneliness in Children

Based on a systematic analysis of the 76 included studies, research on AI-based assessment of psychological loneliness in children is centered around four core themes: assessment objectives, technical methods, data sources, and applicable scenarios. Under each theme, distinct research branches are identified, as shown in Table 2.

4.8.1.1 Topic 1: Assessment Objectives.

Research on AI-based assessment of psychological loneliness in children mainly focuses on two directions: loneliness prediction and the assessment of special population characteristics. Through the combination of multidimensional data and AI technology, the relevant studies achieve precise identification and risk stratification of children's psychological loneliness, providing a basis for subsequent intervention.

On one hand, loneliness prediction is a fundamental core category for AI-based assessment of psycholog-

ical loneliness in children. The primary objective is to model multidimensional child data through AI technology to quantitatively predict outcomes such as the probability of loneliness occurrence, its duration, and intensity fluctuations. Mental health risk screening is a risk-oriented category within this domain, focusing on the co-occurrence patterns of loneliness with psychological disorders such as depression, anxiety, and self-harm tendencies, and building a multi-risk associative assessment framework through AI technology. Notably, unlike previous studies, loneliness occupied a relatively secondary role within the depressive symptom network identified in this body of research.

On the other hand, special group profiling is a precise fit category of AI-based assessment, aimed at developing differentiated loneliness assessment systems based on the developmental characteristics of specific subgroups, including children with ASD, left-behind children, and institutionally isolated children.

4.8.1.2 Topic 2: Technical Approaches. Technical approaches constitute the core methodological link that connects assessment targets with data sources, forming five specific categories: machine learning, network analysis, ecological momentary assessment, structural equation models, and explainable AI methods (XAI, SHAP, and related techniques). These methods enhance the accuracy, scientific rigor, and interpretability of assessment by adapting to the multimodal and dynamic characteristics of children's psychological data.

First, machine learning is the fundamental algorithmic tool for AI-based assessment of children's psychological loneliness, with its core function being the construction of models through training data to automate the identification and prediction of loneliness-related indicators. Researchers use machine learning techniques to overcome the limitations of traditional statistical methods, using children as samples and integrating multidimensional factors such as individual traits, school-based social interactions, and family environment to identify core associated factors of loneliness and characterize the interaction between duration of solitude and social isolation, thereby providing technical support for the precise assessment and intervention of children's loneliness (Qin et al., 2024).

Second, network analysis is a method for characterizing the associations between childhood loneliness and other variable systems, with its core function being the definition of the role of loneliness in the psychological and behavioral systems by constructing inter-variable association networks. Through psychometric network analysis, the relationships between time spent on different digital activities, mental health symptoms, and experiences of social isolation were studied. The results suggest that the context of media use warrants careful examination and underscore the importance of helping young people in establishing healthy digital media habits by encouraging activities that foster social connections and balance with offline experiences (Zhang et al., 2025).

Third, ecological momentary assessment (EMA) is a technique for collecting real-time data from children in natural settings, with a core of capturing the dynamic fluctuations in loneliness through high-frequency, non-intrusive data collection. In digital-environment loneliness research, Scottish researchers adopted a co-designed EMA protocol to continuously record the daily social interactions, real-time loneliness experiences, and mental health status of approximately 200 adolescents aged 12 to 15 years. This ongoing study aims to explore the relationships between online and in-person social interactions and transient loneliness, with the ultimate goal of providing feasible intervention directions for adolescents experiencing persistent loneliness and mental health difficulties (Xiao et al., 2024).

Fourth, the structural equation model is a method for analyzing the causal relationships and mediating mechanisms of childhood loneliness, with its core function being the clarification of direct and indirect effects between variables through confirmatory analysis.

Finally, explainable AI methods are techniques designed to enhance the fit of assessment models to clinical and educational contexts, with their core function being the contribution of each factor to the assessment outcomes through visualization tools, mainly including methods such as XAI and SHAP.

4.8.1.3 Topic 3: Data Sources. Research on AI-based assessment of children's psychological loneliness relies on multidimensional data support. From the 76 included studies, five major data source categories were identified: questionnaire survey data, objective sensor data, electronic health records and clinical data, biological sample data, and social media data. These data types differ in their reliability and validity, ethical risks, and applicable scenarios. Together, they provide an empirical basis for the precise assessment of loneliness.

First, questionnaire survey data constitute the classic benchmark data source for assessing loneliness in children, using the Mature Psychological Scale as a tool to directly capture children's self-perception and subjective experience. The CLS, developed by Asher et al. (1984), was used in 23 studies as label data for training AI models, providing a psychometric reliability and validity standard for the algorithm. Second, objective sensor data captured children's observable behaviors and physiological signals through non-invasive devices such as wearable sensors, environmental sensors, audio and video capture tools, compensating for subjective reports of memory bias and social expectation bias. Third, clinical and health record data encompassing diagnostics and treatment trajectories, comorbidity profiles, and health indicators, provide real-world evidence for the clinical translation of AI-based assessment. Fourth, biological sample data elucidate the biological basis of loneliness at the level of physiological markers and neural signals, providing an objective biological basis for assessment. Finally, social media data encompasses chil-

dren's textual expressions, interactive behaviors, and usage patterns across social platforms, educational applications, and gaming communities, reflecting their true social states and emotional tendencies.

4.8.1.4 Topic 4: Applicable Scenarios. The theme of the application scenarios for AI to assess children's psychological loneliness is the core link between technical methods and practical needs, forming four core categories: clinical medical scenarios, campus educational scenarios, community family scenarios, and digital intelligence virtual scenarios. These contexts, due to the differences in children's activity patterns, data collection conditions, and intervention needs, impose distinct targeted requirements on the accuracy, intrusiveness, and operability of AI-based assessment techniques, collectively contributing to an assessment system covering the entire chain of children's psychological services.

First, the clinical setting focus on children at high risk of psychological problems, with the main objective to assist clinicians in the early identification of loneliness, severity grading, and dynamic tracking of intervention outcomes. AI-based assessment technology needs to meet the triple requirements of high precision, clinical interpretability, and ethical compliance. Social assistance robots, as mental health support tools, have great potential in alleviating loneliness, depression, and anxiety in children (Kabacińska et al., 2025). Secondly, the school scenario targets the general children population, with the core objective of achieving low-cost, high-efficiency screening of lonely groups, thereby providing data to support the allocation of campus mental health service resources. AI assessment technology needs to meet the requirements of low intrusiveness, ease of operation, and group comparability. Network analysis holds great significance for identifying the central symptoms of depression in students and developing appropriate screening tools. Thirdly, the community and family setting constitutes the primary context of children's daily activities, with the core objective of achieving natural, ecological data collection of loneliness and supporting family-level intervention. AI assessment techniques must meet the requirements of non-invasiveness, operability by family members, and long-term stability.

Finally, the digital-virtual setting is a novel type of context shaped by children's digital activities. The core objective is to enable real-time assessment of digital behavior data and support virtual environment-based intervention. AI assessment techniques must meet requirements for real-time performance, compatibility with digital ecosystems, and integration with virtual interaction modalities. Research on virtual group interventions centered on empathy cultivation can enhance adolescents' social connectedness, alleviate loneliness and internalized symptoms, and improve self-compassion. A study focused on 12 virtual lessons for special education students aged 11 to 14 years showed good feasibility and acceptability; however, challenges inherent to virtual forms were noted, and the effect of such interventions still requires further verification through large-sample RCTs (Fox et al., 2024).

4.8.2 Thematic Focus of AI-Based Interventions on Children's Psychological Loneliness

Based on a systematic analysis of 76 core studies, research on AI-based interventions for children's psychological loneliness has been conducted around four core themes: intervention objectives, technical carriers, intervention modalities, and effect validation, with clear research branches identified under each theme, as shown in Table 3.

4.8.2.1 Topic 1: Intervention Objectives. First, loneliness relief represents the fundamental objective of AI-based intervention, aiming to directly reduce loneliness experiences in children and adolescents and improve their psychological well-being through the combination of multiple technologies and intervention modalities. Research in this field focuses on elucidating the mechanisms and influencing factors of loneliness and developing intervention programs tailored to different contexts. From the perspective of symptom network analysis, loneliness is identified as a central depressive symptom among 2458 Chinese rural children with an average age of 10.74 years, offering a symptom-oriented reference for targeted loneliness intervention (Zhang et al., 2024).

Secondly, improving social skills represents the functional enhancement objective of AI-based intervention, focusing on the social functional deficits behind loneliness by leveraging AI technology to enhance social interaction abilities and relationship quality of children and adolescents. This goal requires the development of personalized intervention tools and scenarios based on the differences in social needs across different groups.

Thirdly, reducing the risk of mental illness constitutes the risk management objective of AI-based intervention, focusing on the co-occurrence patterns of loneliness with psychological disorders such as depression, anxiety, and self-harm, and constructing a multi-risk integrated intervention framework. AI technology is employed to identify high-risk groups and specifically block the pathway from loneliness to severe mental illness.

Fourth, the improvement of digital literacy is the environmental adaptation goal of AI-based intervention. In response to the digital lifestyle characteristics of children and adolescents, AI interventions simultaneously enhance their digital media competency and risk awareness, thereby reducing the negative impact of the digital environment on loneliness. Research in this area focuses on the mechanisms linking digital literacy and loneliness, informing the development of programs that combine educational and interventional functions. A machine learning study found that AI education can indirectly reduce the level of loneliness in adolescents by enhancing their interpersonal skills and dig-

ital resilience, with peer relationships and academic emotions serving as key mediating variables (Xie et al., 2022). This goal achieves the dual value of addressing loneliness and adapting to the digital age, reflecting strong contemporary relevance.

4.8.2.2 Topic 2: Technology Platforms. Firstly, smartphone applications serve as portable carriers for AI-based intervention. Their core value lies in the personalized functional design of mobile platforms, enabling loneliness intervention to be delivered anytime and anywhere, and adapting to the digital lifestyle contexts of children and adolescents.

Secondly, social robots are interactive carriers of AI-based intervention, with their core function residing in physical or remotely operated robot devices that simulate authentic social scenarios and provide safe, low-stress social interaction experiences for children and adolescents. Studies on pediatric hospital settings have shown that social robots can effectively alleviate children's loneliness, depression, and anxiety, while also helping healthcare workers and patients build a harmonious relationship; their acceptability has been consistently recognized by children, parents, and healthcare professionals alike (Kabacińska et al., 2025).

Thirdly, chatbots serve as an immediate carrier of AI-based intervention, with their core function consisting in natural language interaction technology, providing 24/7, low-threshold emotional support and social guidance for children and adolescents, transcending temporal and geographic limitations. The REAL bot, developed for rural LGBTQ+ youth, provides guidance on social media use through Facebook and Instagram platforms, effectively reducing the sense of social isolation among the target population. The intervention received high scores for both acceptability and usability (Escobar-Viera et al., 2023).

Fourth, online platforms serve as the resource integration carriers for AI-based intervention. At its core, it integrates online communities, course modules, and interactive tools to provide group-based support and systematic intervention for children and adolescents, thereby enhancing the sustainability and diversity of intervention resources. Research shows that online youth work platforms help adolescents cope with negative online experiences and loneliness by integrating functions such as social media navigation, skill development, and risk alerts. Their core value lies in connecting professional support and peer resources to form intervention synergy (Todorovic et al., 2025). The EMPOWER YOUTH online platform offers six modules of preventive intervention for adolescents in foster care, incorporating loneliness relief as a secondary intervention goal and enhancing the systematic nature of the intervention through a combination of group interaction and professional guidance (Wagner et al., 2022).

Finally, AR/VR serve as immersive carriers of AI-based intervention, with their core function being residing in the simulation of authentic social scenarios or the creation of virtual interactive environments, helping children and adolescents improve their social skills, reduce social avoidance, and alleviate loneliness. In a robot summer camp intervention, adolescents with ASD and typically developing peers established social connections through collaborative robot programming and virtual task challenges, significantly reducing social anxiety and loneliness in the ASD group (Kaboski et al., 2015). This carrier effectively transcends the limitations of real-world social scenarios through immersive experiences and scenario simulation, providing a safe practice environment for children with weak social skills.

4.8.2.3 Topic 3: Intervention Modalities. Firstly, cognitive behavioral intervention is a core modality that focuses on the correction of cognitive biases and behavioral guidance. Its central mechanism involves alleviating loneliness and associated psychological problems by adjusting the negative thinking patterns and maladaptive behavioral habits in children and adolescents.

Secondly, positive psychology intervention is an intervention modality that focuses on identifying strengths and building positive experiences, with its core mechanism centered on cultivating positive psychological qualities such as empathy, self-acceptance, and social connectedness in children and adolescents, thereby enhancing psychological resilience and indirectly alleviating loneliness. The Inspiring Comfort online intervention program conducted 12 sessions of empathy and compassion training for students aged 11 to 14 years in special education schools. After the intervention, participants showed significant reductions in feelings of loneliness and depression, improved self-compassion, and high levels of satisfaction, confirming the beneficial effect of cultivating positive psychological qualities on loneliness (Fox et al., 2024).

Thirdly, peer support intervention is an intervention model that focuses on group interaction and social connection construction, with its core mechanism centered on establishing peer communication platforms to enable children and adolescents to reduce loneliness and enhance social skills through mutual support and shared participation. Research on online youth work shows that youth workers facilitated peer interaction activities through digital platforms, helping adolescents to share negative online experiences and collectively address loneliness. Following the intervention, participants showed significant improvements in social connectedness and enhanced ability to manage risks in online environments (Todorovic et al., 2025).

Fourth, family-participatory intervention is an intervention model focused on optimizing the family system, with its core mechanism centered on adjusting family interaction patterns, improving parent-child relationships, and providing emotional support for children and adolescents, thereby reducing the conditions for the development of loneliness.

Fifth, personalized adaptive intervention is a precision intervention model focused on individual differences. The core mechanism is to identify risk factors for loneliness, psychological traits, and differences in needs of children and adolescents, and customize exclusive intervention plans to enhance the adaptability and effectiveness of the intervention.

Finally, multimodal integrated intervention is a comprehensive intervention model focused on the synergy of multiple resources, with its core mechanism being the integration of different technical carriers, intervention methods, and service providers to form an intervention synergy that comprehensively addresses the loneliness needs of children and adolescents. The REAL bot intervention, developed for rural LGBTQ+ youth, integrates chatbots, social media platforms, and peer support resources, using AI to guide social media skills and foster online peer communities; the intervention demonstrated high feasibility and user satisfaction, and effectively reduced social isolation among the target population (Escobar-Viera et al., 2023).

4.8.2.4 Topic 4: Effect Validation. First, quantitative assessment indicators are the fundamental category of effect validation, providing precise measurement of improvements in loneliness and associated psychological states through objective indicators such as standardized scales, statistical model parameters, and behavioral quantification data, thereby ensuring the reproducibility and comparability of validation outcomes. In the study on Internet addiction among adolescents, standardized tools such as the UCLA Loneliness Scale and the Patient Health Questionnaire-9 (PHQ-9) were used to quantify loneliness and depression levels. When combined with a support vector machine model, loneliness was identified as the core feature of the classification of Internet addiction, providing a quantified criterion for evaluating intervention effects. Supported by objective data, this category has become the most widely used basic foundation in effect validation.

Secondly, qualitative feedback analysis is a complementary and deepening category of effect validation. At its core, it involves the collection of qualitative data, such as subjective experiences, interview records, and feedback from children and adolescents, parents, and intervention implementers, to explore the underlying mechanisms and potential limitations of intervention effects, thereby addressing the limitations of quantitative indicators alone. In a study of social robot intervention in a pediatric hospital setting, an online survey of 71 children and parents and focus group interviews with 10 healthcare staff were conducted to capture the perspectives and experiences of all stakeholders regarding the robot's role in alleviating loneliness. Findings revealed broad recognition of the robot's interactivity and safety, while also identifying potential areas for improvement, such as technology fit (Kabacińska et al., 2025).

Thirdly, long-term follow-up represents a continuous category of effect validation, with its core involving the extension of the evaluation period to track the stability and persistence of the intervention effect, avoid misinterpretation of short-term outcomes, and ensure the long-term practical value of the intervention. A randomized controlled trial conducted a two-year follow-up assessment among primary school children, tracking the sustained reduction in loneliness after a social-emotional learning intervention and verifying whether the intervention gains persisted over time (Hennessey et al., 2021).

Fourth, controlled experiment represents a causal inference category of effect validation, with its core involving the establishment of intervention and control groups to eliminate confounding factors, clarify the specific effects of the intervention, and strengthen the causal credibility of the validation results.

4.9 Theoretical Construction and Application Mechanisms

As shown in Fig. 6A, based on the systematic empirical review of AI application in the assessment and intervention of psychological loneliness in children, this study further integrates five core theoretical perspectives to propose a multidisciplinary integrated theoretical framework aligned with children's development principles and the logic of technology application. This framework places the assessment and intervention of loneliness in children at its core and systematically explains the theoretical basis and practical logic of AI technology application across five dimensions: cognitive development, learning construction, behavior shaping, neural mechanisms, and technical adaptation. It achieves a deep integration of theoretical perspectives and empirical findings. Among them, the cognitive developmental stage theory, with the four stages of sensorimotor, preoperational, concrete operational, and formal operational development, provides fundamental guidance for the age-appropriateness of AI assessment and intervention, ensuring that technology application conforms to children's physical and psychological developmental trajectories. Constructivist theory, with active construction, situational learning, and scaffolding support as its core elements, provides the conceptual logic for the design of AI-based social intervention tools, emphasizing the promotion of autonomous internalization of social skills through dynamic scaffolding. Behaviorist theory, with behavioral reinforcement, social skill shaping, and positive feedback as its core mechanisms, provides theoretical support for ultra-personalized and real-time AI intervention, providing an operational pathway for breaking the vicious cycle of loneliness. Neuroscience theory, encompassing neural activity, neural mechanisms, brain structure, and cognitive function as its core dimensions, provides physiological-level evidence for multimodal AI assessment and targeted intervention, and supports the positive development of relevant brain regions through the principle of neural plasticity in AI-based social training. Finally, technology phenomenology, with the tripartite interaction among technology, the

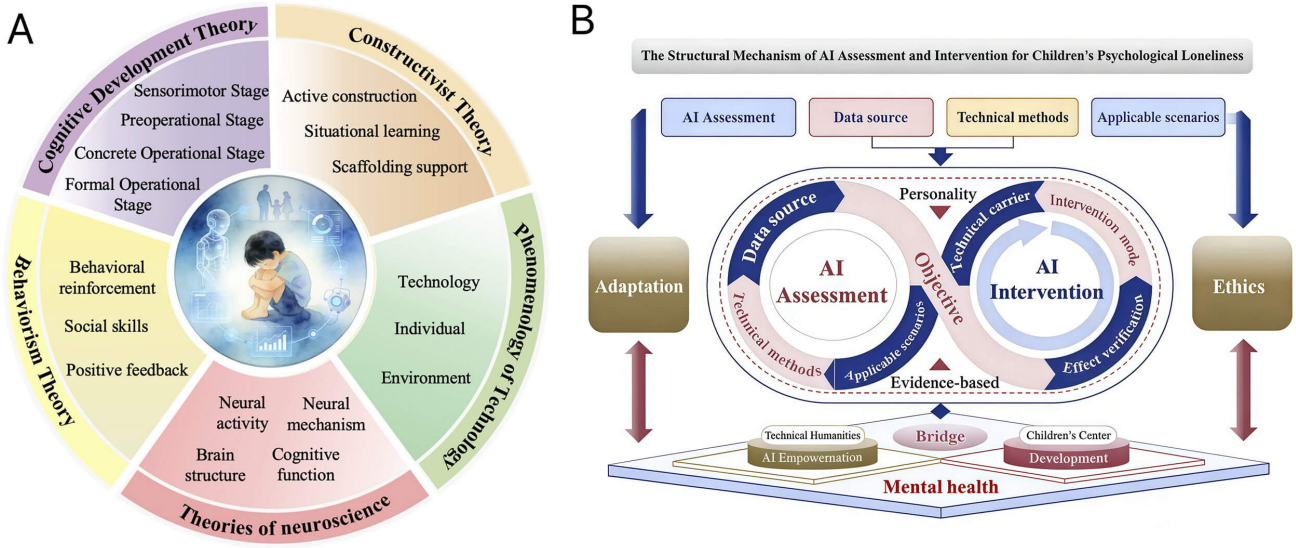


Fig. 6. Theoretical construction and application mechanism of AI-based assessment and intervention for children's psychological loneliness. (A) Multidisciplinary integrated theoretical construction. (B) Application mechanism. AI, artificial intelligence.

individual, and the environment, delineates the ecological adaptation criteria for AI assessment and intervention, emphasizing that technology application must be aligned with children's real-life contexts to ensure intervention effectiveness.

The multidisciplinary integrated theoretical framework proposed in this study represents an analytical paradigm derived from systematic empirical review. It not only incorporates the core findings of prior empirical research but also provides an analytical approach that is both theoretical grounded and practically operationalizable for subsequent related research, achieving an organic integration of evidence-based synthesis and theoretical construction. It effectively clarifies the logical boundaries between theoretical deduction and empirical induction, thereby significantly enhancing the rigor and internal coherence of the research.

Furthermore, based on the findings presented above, this study proposes a conceptual integrated framework for AI-based assessment and intervention of psychological loneliness in children, on the basis of literature mapping and scope definition, as shown in Fig. 6B. Oriented toward children's mental health, this framework systematically maps the technical pathways, application scenarios, and core elements of existing research across three dimensions—assessment, intervention, and humanistic empowerment–providing a theoretical reference for subsequent research.

Firstly, the framework adopts behavioral representation and psychological perception as its two primary observational dimensions, and is composed of an adaptation system, multidimensional evaluation, and ethical standards to form the overarching mapping framework. Among them, the adaptation system focuses on the risk screening pathways and algorithmic model application features in existing research; multidimensional evaluation achieves structured benchmarking based on data types and research designs reported in the existing literature; and ethical standards are derived from a synthesis of compliance considerations across existing research application scenarios. Together, these three components constitute the scope definition and mapping basis of the review. Secondly, the core mapping link includes two major modules: AI assessment and AI intervention. The AI assessment module systematically organizes data sources, technical methods, target populations, and outcome indicators reported in existing literature. The AI intervention focus on intervention models and effect validation as its core intervention effects, and based on the assessment outcomes, it provides individualized guidance while enabling dynamic iteration of intervention strategies. Finally, the two modules are interconnected through the dual principles of technological adaptation and humanistic orientation. The technological dimension focuses on the existing research features such as multimodal data fusion and iterative intervention technology, while the humanistic dimension, guided by a child-centered orientation, conceptually synthesizes the humanistic empowerment elements of existing technologies. The framework ultimately presents the core directions and practical logic of current research through implementation pathway mapping, and combines behavioral feedback indicators such as social interaction and social withdrawal to provide theoretical references for subsequent optimization of assessment and intervention cycles.

5. Discussion

5.1 Overall Research

This study conducts a systematic review of AI-based assessment and intervention of children's psychological

loneliness, strictly following the PRISMA guidelines. Literature was searched across the WOS, Scopus, and CNKI core databases from 2015 to 2025, and following a rigorous screening, 76 empirical studies were included. The research clearly demonstrates that this field has evolved through three stages: nascent exploration, steady growth, and rapid development, establishing four major research clusters centered on research themes, core AI technologies, assessment systems, and intervention frameworks. The study proposes an AI-based assessment system covering assessment goals, technical methods, data sources, and application scenarios, as well as an AI intervention framework encompassing intervention objectives, technical carriers, intervention models, and effect validation, and advances a three-dimensional structural mechanism of assessment, intervention, and humanistic empowerment.

The overall research is supported by multidisciplinary theories, systematically delineates technical pathways and practical logics, and reveals the core value of AI in the precise identification, personalized intervention, and inclusive service delivery for children's loneliness, providing a theoretical basis and practical reference for the digital and intelligent transformation of children's mental health services.

5.2 Distinctions from Existing Literature

5.2.1 Refined Scope and Identification of a Domain Gap

Previous systematic reviews in this field are often characterized by broad scope and lack of thematic focus. Most studies have addressed broad topics such as adolescent mental health, AI applications in child-related domains, and the assessment and intervention of loneliness in general, without achieving a targeted review of the specific intersection of AI and children's psychological loneliness. Although some studies have involved child populations, loneliness has largely been addressed as a single dimension of mental health in an unsystematic manner, without establishing a cohesive framework connecting AI technology to the assessment and intervention of children's psychological loneliness. This has led to a lack of targeted and application-oriented research conclusions.

The present study strictly follows the topic selection standards of systematic reviews, positioning children's psychological loneliness as the central research focus, precisely defining the application scenarios of AI technology, and focusing on two core issues: the optimization of assessment methods and the construction of intervention models. Compared with previous generalized systematic reviews, the present study is more precisely targeted in its scope, effectively filling the domain gap in the full-chain research on AI-empowered assessment and intervention of children's psychological loneliness. It provides a clear entry point and reference framework for subsequent research in this specific field, and offers more precise theoretical support and practical guidance for both academic research and applied practice in related fields.

5.2.2 Dynamic Extension of the Period and Incorporation of Frontier Research

Existing systematic reviews in this field are generally characterized by outdated search cutoff dates and insufficient coverage of recent advances. The literature search cutoffs of most studies are concentrated prior to 2022, failing to fully capture the application advances of frontier technologies such as generative AI, large language models, and intelligent interactive robots in the field of children's psychology since 2023. This has led to research conclusions that fail to reflect the latest developmental trends in the field and lack adaptability and explanatory power for current technological practice. Furthermore, due to limitations in database indexing and literature search strategies, some prior domestic studies have demonstrated insufficient coverage of international frontier literature published in the past five years, further weakening the timeliness and global perspective of the research.

This study optimizes the literature search strategy by setting the search time span from 2015 to 2025, fully covering the full developmental trajectory of the field from initial exploration through steady growth to rapid expansion. It particularly includes empirical research findings on frontier technologies such as generative AI, multimodal interaction technology, and digital twins in the assessment and intervention of psychological loneliness in children from 2023 to 2025, comprehensively presenting the dynamic technological evolution of the field. Compared with existing systematic reviews, the temporal dimension of this study has been significantly extended, not only ensuring the timeliness and relevance of the research conclusions but also accurately reflecting the integration trajectory of AI technology within the field of children's psychological loneliness, providing more comprehensive and forward-looking literature support for identifying research hotspots and future development directions in this field.

5.2.3 Systematic Integration of Technology Review and Framework Proposal

Existing systematic reviews in this field are often fragmented and lack cohesion in their treatment of technology. Most studies have examined a single type of technology alone, without forming a systematic and structured review of AI technology applications across the field of psychological loneliness in children. Although some studies have mentioned multiple technical approaches, they lack integrated analysis of the functional positioning, applicable scenarios, and application logic of these technologies, resulting in insufficient guidance and limited operability for technology application.

This study transcends the limitations of prior technology reviews through in-depth literature analysis and integration, systematically identifying four core technology types, namely machine learning algorithms, intelligent social robots, VR technology, and large language models, and clarifying the functional roles and applicable logic of each

technology type in the assessment and intervention of children's psychological loneliness. Compared with existing systematic reviews, this study provides a comprehensive overview of AI technology application in this field, providing practical and scalable technical pathways and operational paradigms for related practice, and establishing a solid theoretical foundation for subsequent technological research and application optimization.

5.2.4 Deep Integration of Theoretical Mechanisms and Proposal of an Application Mechanism

Prior systematic reviews and meta-analyses in this area have mainly focused on empirical summaries, with limited theoretical support. Research findings have mostly remained at the level of summarizing and describing existing empirical studies, lacking in-depth theoretical explanation of the mechanisms and underlying logic between AI and psychological loneliness in children. Some studies have introduced a single theoretical framework as an analytical perspective but have failed to achieve the integration and connection of multidisciplinary theories, resulting in insufficient theoretical explanatory power and limited systematic power, thereby failing to support rigorous theoretical mechanisms and application mechanism development in this field.

This study adopts an interdisciplinary perspective, integrating cognitive developmental theory, constructivist theory, behaviorist theory, neuroscience theory, and technology phenomenology theory, to construct an analytical framework supported by multidisciplinary theories. As such, the present study extends beyond the limitations of prior theories and proposes a three-dimensional structural framework encompassing assessment, intervention, and humanistic empowerment, clarifying the precise role of AI technology at the assessment stage, the personalized logic operative at the intervention stage, and the pathways through which the humanistic dimension permeates technology application. Compared with existing systematic reviews, the theoretical system developed in this study is more comprehensive and explanatory. It not only deepens the theoretical understanding of the relationship between AI and psychological loneliness in children but also provides a novel analytical framework and research perspective for theoretical advancement in this field.

5.3 Research Limitations and Future Directions

5.3.1 Research Limitations

First, the review is limited by an insufficient analysis of technical ethics and safety risks. Key ethical issues arising from the application of AI, including the protection of children's data privacy, algorithmic bias, and algorithmic opacity, are not systematically addressed. Furthermore, the potential risks of excessive reliance on virtual interaction, which may undermine children's real-world social skills and adversely affect their emotional development, are not examined in depth. Consequently, the discussion of the ethical dimension remains incomplete.

Second, the consideration of practical transformation and implementation bottlenecks is insufficient. This research provides limited analysis of the practical obstacles to technology implementation, failing to fully address issues such as high hardware costs, difficulties in grassroots-level promotion, complex operation, and maintenance requirements. It also lacks discussion of the practical challenges faced by practitioners such as insufficient interdisciplinary training among school psychologists and medical personnel, and inadequate operational capabilities, hindering large-scale promotion.

Third, the review insufficiently accounts for cultural and population heterogeneity. The impact of cultural differences on the manifestation, identification, and intervention outcomes of children's loneliness is not fully analyzed, and the cultural adaptability and cross-cultural validity of the AI models examined remain insufficient. Additionally, the discussion of personalized adaptation and service fairness for special children with special needs, such as those with autism, left-behind children, and children with disabilities, is limited, compromising the universality and inclusiveness of the research.

5.3.2 Future Directions

Firstly, a comprehensive technical ethics and security framework should be established to strictly regulate the collection, storage, and use of children's multimodal data, enhancing privacy protection and data security. Efforts should also be directed to increase the transparency and interpretability of algorithms, reducing algorithmic bias caused by data deviation, and preventing inequitable outcomes in AI-based assessment and intervention. Additionally, the intensity of virtual interaction should be appropriately regulated to prevent excessive use from negatively affecting children's real-world social skills and emotional development.

Secondly, efforts should be accelerated to promote the practical transformation and inclusive application of AI technology, with a focus on developing low-cost, lightweight, and easy-to-maintain intelligent assessment and intervention tools, with the aim of reducing hardware and deployment costs and improve accessibility in grassroots schools, communities, and resource-limited settings. In parallel, an interdisciplinary training system integrating psychology, education and computer science should be established to strengthen the practical competencies of frontline school psychologists and medical staff, and to enhance practitioners' capacity for AI tool application and risk management, thereby providing the necessary support for large-scale implementation.

Finally, research on cultural adaptability and population heterogeneity should be strengthened through cross-cultural comparative validation, and the recognition accuracy of AI models in identifying loneliness in children from diverse cultural backgrounds should be optimized to im-

prove the cultural adaptability of intervention content. For children with special needs, such as those with autism, left-behind children, and children with disabilities, differentiated and personalized assessment indicators and intervention plans should be developed to balance service equity and precision, thereby promoting the scientifically grounded, safe, and inclusive application of AI technology in children's mental health.

6. Conclusions

This systematic review was conducted in strict accordance with PRISMA guidelines, involving a systematic search and screening of literature from the Web of Science, Scopus, and CNKI core databases from 2015 to 2025. A total of 76 empirical studies were ultimately included, through which the current state of application, technical pathways, and practical mechanisms of AI in the assessment and intervention of psychological loneliness in children were systematically examined, yielding a comprehensive set of research conclusions.

Current research on the application of AI in the assessment and intervention of psychological loneliness in children has followed a three-stage evolutionary trajectory characterized by nascent exploration, steady growth, and rapid development. Global publication output has continued to rise, forming a research landscape centered on China and the United States, with broad collaborative participation from multiple countries. The research subjects examined cover children with ASD, typically developing children and adolescents, disadvantaged and special needs children, and high-risk institutionalized adolescents, forming a stratified and differentiated research framework. This study proposes an AI assessment system covering assessment goals, technical methods, data sources, and application scenarios, as well as an AI intervention framework comprising intervention goals, technical platforms, intervention models, and effect verification. Four core technologies were systematically identified. Technical application logic underlying multimodal perception, personalized adaptation, and dynamic iteration was further delineated.

At the theoretical level, this study integrates cognitive development theory, constructivism theory, behaviorism theory, neuroscience theory, and technology phenomenology, proposing a three-dimensional application mechanism of assessment, intervention, and humanistic empowerment. This framework achieves a deep integration of technological application with the principles of children's physical and mental development and humanistic care, thereby providing an integrated theoretical support and practical paradigm for the advancement of the field. This research confirms that AI, with its advantages of multimodal perception, precise identification, personalized intervention, and universal coverage, can effectively address the structural limitations of traditional assessment and intervention models, which are constrained by reliance on subjective self-report, scarcity of professional resources, and limited population coverage. These capabilities hold significant applied value for the early identification, dynamic monitoring, stratified intervention, and universal services addressing loneliness, thereby providing a scientific basis for the digital and intelligent transformation of children's mental health services.

Overall, the present review addresses the gap in the systematic review literature of AI in the prevention and control of psychological loneliness in children, examined through the perspective of the integration of technology and humanistic care. The theoretical framework and practical mechanisms proposed herein may serve as a reference for academic research, applied practice, and policy formulation, and help promote the development of a more inclusive, scientifically grounded, and universally accessible children's mental health support system.

Availability of Data and Materials

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Author Contributions

DML was responsible for design and validation. XYH was responsible for research method design. YQW was responsible for research review and research design analysis. All authors participated in the writing of the original manuscript, as well as the review and editing of the manuscript, and approved the final version. All authors are responsible for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflicts of Interest

The authors declare no conflicts of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/BP50496.

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