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Virtual Reality Technology in Autism Rehabilitation:Current Applications and Future Prospects

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Abstract: This study used Biblioshiny, a bibliometric analysis tool, to systematically review and visualize the literature on virtual reality technology in autism rehabilitation indexed in the Web of Science database from 2000 to 2025. The results showed a continued increase in research activity in this field. Major research directions included social skills training, attention training, emotion recognition and regulation training, daily adaptive skills training, vocational preparation and interview training, and interventions for comorbid conditions. The application of virtual reality in autism rehabilitation presents both potential advantages and limitations. Future research is expected to move toward multidimensional collaborative interventions, the integration and upgrading of technological forms, deeper AI-driven approaches, and a stronger human-centered design orientation.

Keywords: Virtual Reality; Autism Spectrum Disorder, Rehabilitation Training, Current Applications and Future Prospects; Biblioshiny

1. Introduction

Autism spectrum disorder (ASD), commonly referred to as autism, is a complex neurodevelopmental disorder characterized primarily by difficulties in social interaction, impairments in verbal and nonverbal communication, and restricted and repetitive patterns of behavior (Hu & Liu, 1998). The etiology of ASD is complex and is thought to involve multifaceted interactions among genetic, epigenetic, and environmental factors (Elsabbagh, 2020; Fett-Conte et al., 2015; Sauer et al., 2021). The American Psychiatric Association defines the core features of ASD as persistent deficits in reciprocal social communication and social interaction, together with restricted, repetitive patterns of behavior, interests, or activities (American Psychiatric Association, 2013). Beyond these core features, many individuals with ASD also experience difficulties in emotional regulation, sensory processing, cognitive and executive functioning, and co-occurring conditions such as specific phobias (Sepehri Bonab et al., 2025; Leekam et al., 2007; Ji et al., 2022; Davis III et al., 2024).

Virtual reality (VR) refers to a computer-generated, three-dimensional simulated environment that delivers multisensory stimuli—typically visual, auditory, and tactile stimuli—through specialized electronic devices. By enabling users to interact with simulated environments in a realistic manner, VR can create a subjective sense of immersion (Emmelkamp & Meyerbröker, 2021). For individuals with ASD, the safety, controllability, and multisensory features of VR environments may support personalized, adaptive, and engaging interventions. Such interventions have been used to support the development of core skills, including social-emotional, cognitive, and attentional skills, and may facilitate the transfer of these skills to real-world contexts through realistic virtual scenarios. In addition, real-time data recording can provide timely feedback to inform intervention delivery (Fu et al., 2025; Mesa-Gresa et al., 2018).

In recent years, researchers worldwide have proposed innovative approaches to addressing challenges in autism rehabilitation through emerging technologies such as virtual reality (Soltiyeva et al., 2023). Research on virtual reality interventions for autism can be traced back to the late twentieth century and has grown rapidly over the past two decades. Existing studies have covered areas such as social-emotional skills training, interventions that integrate virtual reality with other technologies, and the evaluation of intervention outcomes. Against this background, the present study uses Biblioshiny to conduct a visual analysis of the current status, research hotspots, and developmental trends in domestic and international studies on virtual reality interventions for autism. By examining major international research directions and future trends in this field, this study aims to provide a broader perspective for the research and application of virtual reality interventions for autism in China.

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2. Data Source

This study used journal articles indexed in the Web of Science (WoS) Core Collection as the data source. An All Fields search was conducted using Boolean logic with the following search string: ("Virtual Reality" OR "VR") AND ("Autism" OR "ASD"). The publication period was limited to 2000–2025, the document type was restricted to "Article," and the language was limited to English. After removing duplicate records, a total of 790 valid articles were identified. The search was conducted on September 4, 2025.

To reflect the current state of international academic communication and development in this field, the literature included in the analysis mainly consisted of English-language articles. At the same time, this study paid particular attention to studies led by Chinese scholars, including those from mainland China, Hong Kong, Macao, and Taiwan, in order to provide a more comprehensive understanding of Chinese scholars' participation in the international research landscape and to offer a more reliable basis for the development of this field in China.

3. Temporal Trends and Geographical Distribution of Research on Virtual Reality in Autism Rehabilitation

3. 1 Annual Publication Trend (2000–2025)

As shown in Figure 1, from 2000 to 2025, the annual number of international publications on VR in ASD rehabilitation generally showed a fluctuating upward trend, indicating a rapid increase in research output and growing scholarly attention to this field in recent years. Based on this trend, the development of research in this area can be broadly divided into three phases. The first phase, from 2000 to 2012, was a period of preliminary exploration, during which the annual number of publications remained low. In particular, research activity was nearly stagnant from 2000 to 2001 and from 2003 to 2007. The second phase, from 2013 to 2019, was a period of steady growth. Compared with the previous phase, the number of publications increased more noticeably, although the overall growth rate remained relatively stable and followed an approximately linear pattern. The third phase, from 2020 to 2025, was a period of rapid growth, during which the annual number of publications increased substantially, with local peaks observed in 2020 and 2024.

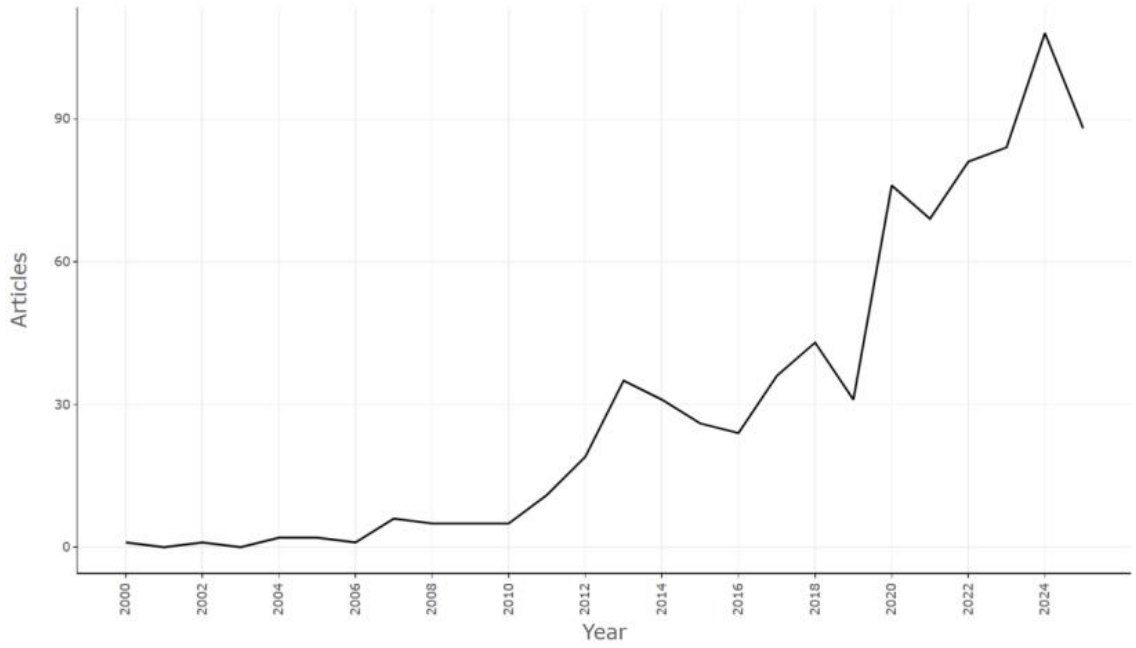

Figure 1. Annual Publication Output of Research on the Application of Virtual Reality in Autism Spectrum Disorder Rehabilitation from 2000 to 2025

3. 2 National and Regional Research Output Distribution

The 790 articles analyzed in this study involved authors from 97 countries and regions. Based on the corresponding authors' countries or regions, the top ten contributors were the United States (320 articles), Sweden (96 articles), the United Kingdom (88 articles), China (68 articles), Italy (63 articles), Spain (57 articles), India (49 articles), France (42 articles), Canada (40 articles), and Australia (38 articles). As shown in Figure 2, which presents national research output based on the institutional affiliations of all authors, the United States ranked first in both publication output and research participation in this field. It substantially outpaced Sweden and the United Kingdom, which formed the second tier, indicating its leading position in this area of research. China entered this field relatively late. According to the Web of Science Core Collection, the first Chinese publication in this field appeared in 2010, considerably later than the first publication from the United States in 1979. Nevertheless, within 15 years, China has risen to fourth place globally, with

68 publications, suggesting considerable potential for future development.

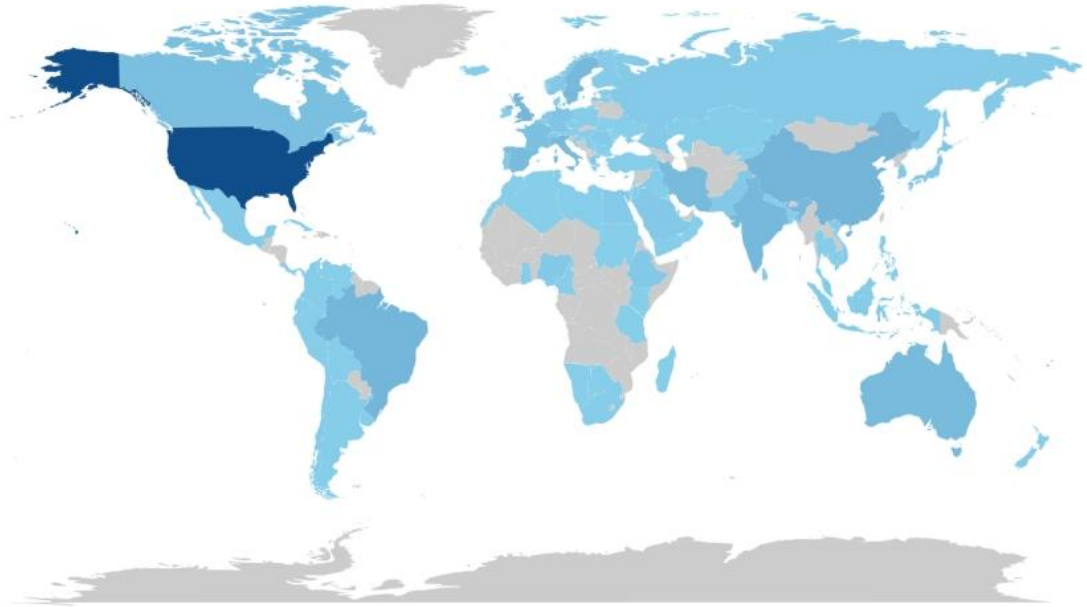

Figure 2. National Distribution of Research Output on Virtual Reality in Autism Spectrum Disorder Rehabilitation from 2000 to 2025

4. Main Application Fields of VR in Autism Rehabilitation

4. 1 Overview of Research Hotspots Based on Keyword Analysis

Applications of Virtual Reality in Different Areas of Autism Rehabilitation

The keywords analyzed in this study were derived from the "Author Keywords" field in the Web of Science database, as these terms more directly reflect the research community's primary concerns and priorities related to this topic. During data processing and visualization, terms with repeated or equivalent meanings were merged, including abbreviations and singular/plural variants such as "autism spectrum disorder," "ASD," and "autism spectrum disorders," as well as semantically similar terms such as "emotion recognition," "facial emotion recognition," and "identification of emotional expressions." In addition, when generating the keyword word cloud and frequency table, the core search terms "autism spectrum disorder" and "virtual reality" were excluded to better highlight more specific subtopics within the field. Finally, the top 30 keywords by frequency were selected for visualization. As shown in Figure 3 and Table 1, research on VR in ASD rehabilitation can be broadly categorized into several areas, including social skills training, attention training, emotion recognition and regulation training, daily adaptive skills training, and vocational preparation and interview training.

Figure 3. Keyword Word Cloud of Research on Virtual Reality in Autism Spectrum Disorder Rehabilitation from 2000 to 2025

Table 1. Keyword Frequency Statistics of Research on Virtual Reality in Autism Spectrum Disorder Rehabilitation from 2000 to 2025: Top 30 Keywords

Rank	Keyword	Frequency	Rank	Keyword	Frequency
1	augmented reality	34	16	anxiety	14
2	social	26	17	eye-tracking	14
3	children	24	18	intellectual disability	14
				attention-deficit/hyperactivity	
4	technology	24	19	disorder	13
5	social-skills	23	20	adults	11
6	employment	22	21	eye tracking	11
7	training	20	22	facial emotion recognition	11
8	social cognition	19	23	machine learning	11
9	vocational rehabilitation	18	24	rehabilitation	11
10	serious game	17	25	transition	11
11	education	16	26	assessment	10
12	learning	16	27	disorder	10
13	attention	15	28	skill	10
14	interaction	15	29	social interaction	10
15	joint attention	15	30	adolescents	9

4.2 Social Skills Training

Individuals with ASD often experience significant difficulties in social communication, emotional expression, and social interaction, which may manifest as challenges in recognizing social cues, maintaining conversations, and understanding complex social situations. These difficulties can limit their daily social participation and the development of interpersonal relationships (Ip et al., 2018). VR technology provides repeatable and low-risk social scenarios for participants (Ke et al., 2022). When combined with multisensory interaction, VR may enhance engagement and support the internalization of social communication skills (Atsalaki & Kazanidis, 2025). As one of the most widely studied areas of VR-based interventions for autism, social communication research is closely associated with keywords such as "social," "social skills," "social cognition," and "interaction."

Within this theme, VR-based interventions for individuals with ASD can be further divided into three subcategories: (1) conversational skills, (2) social rules and situational learning, and (3) peer relationship building.

Conversational skills include initiating, maintaining, and ending conversations, as well as turn-taking and topic shifting. Didehbani et al. (2016) conducted a 5-week virtual reality social cognition training program for children with high-functioning autism, in which participants interacted through personalized avatars in simulated social settings such as classrooms, parks, and restaurants. The training focused on conversational initiation, topic maintenance, emotional responses, cooperation, and social problem-solving, with real-time feedback provided during each session. The preliminary findings suggested that VR-based training may support improvements in key social skills within a relatively short intervention period.

Similarly, Yeh and Meng (2025) developed the "Art Tour with Classmate" system to help students practice conversational behaviors in virtual scenarios, including classrooms, exhibition halls, restaurants, and parks. The intervention involved tasks such as greeting, inviting, ordering food, saying goodbye, and responding to unexpected social situations. Their findings showed improvements in reaction speed, sentence structure, and conversational expressiveness. However, participants with ASD did not show the same shift toward actively seeking help as students with social difficulties, suggesting that future VR-based conversational training should further consider the specific support needs of individuals with ASD.

Social rules and situational learning involve the acquisition of rule-based behaviors, such as raising one's hand in class, standing in line, and using polite language. Ip et al. (2018) developed a VR-based program using the CAVE system to enhance emotional and social adaptation skills in children with ASD. The program included six VR scenarios, four of which simulated real-life social situations, including home routines, school bus and classroom settings, a library, and a school store. These scenarios required children to apply social rules in contexts such as waiting for an elevator, following teachers' instructions, sharing seats in the library, and borrowing books at the circulation desk. After 28 training sessions, children with ASD showed improvements in several abilities, including social interaction skills, and the intervention demonstrated potential for transfer to real-life situations. These findings suggest that VR-based situational learning may help children with ASD acquire specific social rules.

Peer relationship building refers to the ability to engage in peer interaction and cooperation during VR-based

training. Gabrielli et al. (2023) developed Zentastic, a multiplayer collaborative VR adventure game designed to train social skills in adolescents with ASD. In this game, participants used VR headsets and controllers to complete cooperative tasks that required two to four players to work together, with task difficulty increasing progressively. A feasibility study involving 12 boys with ASD suggested that the Zentastic multiplayer VR game may support improvements in adolescents' social skills and was perceived as highly enjoyable. These findings indicate that gamified VR training may be a promising approach to increasing the motivation of individuals with ASD to participate in intervention programs.

4.3 Emotion Recognition and Regulation Training

In many studies on social skills, the role of VR in emotion recognition and emotion regulation among individuals with ASD has also been discussed, with related keywords including "anxiety" and "facial emotion recognition." Within this theme, VR-based interventions for individuals with ASD can be further divided into two subcategories: (1) facial expression recognition and (2) emotion regulation and anxiety coping.

Regarding facial expression recognition, Van Pelt et al. (2022) developed the Dynamic Interactive Social Cognition Training in Virtual Reality (DiSCoVR) system, a VR-based social cognition training program for individuals with mental disorders. In its emotion perception module, participants were trained to recognize emotional expressions in virtual environments, such as identifying the emotions of virtual characters in a shopping street scenario. The training gradually increased in difficulty by requiring faster responses and recognition of emotions at lower intensity levels. In a 12- to 16-week intervention involving 26 adults with ASD, 22 participants completed both baseline and post-intervention assessments. Their scores on the Facial Expressions of Emotion: Stimuli and Tests (FEEST) improved significantly from baseline to post-intervention, and the improvement was maintained at follow-up, suggesting that the intervention effects may have been sustained to some extent. However, because the study did not include a control group, further controlled studies are needed to validate its effectiveness.

In terms of emotion regulation and anxiety management, researchers have developed VR-based programs that are either applicable across multiple scenarios or tailored to specific contexts, such as dental examinations. Ip et al. (2018) developed a VR-based program to enhance emotional and social adaptation skills in children with ASD. The program included a virtual four-season environment for adaptation and relaxation, as well as four real-life scenarios—morning routines at home, the school bus and classroom, the library, and the school store—for emotion regulation training. After 28 training sessions, 94 children with ASD showed significant improvements in emotional expression and regulation.

In addition, individuals with ASD often experience high levels of anxiety and resistant behaviors during dental visits because of social interaction difficulties, sensory sensitivities, and communication challenges, which may affect the implementation and outcomes of oral treatment. Al Kheraif et al. (2024) examined the effects of a VR intervention on anxiety and cooperation during dental examinations among 140 children and adolescents with ASD aged 4–18 years. Participants were randomly assigned to a control group receiving routine dental examination or a VR group immersed in a soothing nature-based virtual environment. The results showed that, although baseline anxiety and cooperation levels were comparable between the two groups, the VR group had significantly lower anxiety scores and significantly higher cooperation levels after the intervention. These findings suggest that VR-generated natural environments may help children and adolescents with ASD regulate emotions, reduce anxiety, and improve cooperation in specific clinical contexts.

4.4 Attention Training

Although attention difficulties are not among the primary diagnostic criteria for ASD, they are relatively common in individuals with ASD (Sanku et al., 2023) and may significantly affect their learning, social interaction, and daily functioning (Razzak et al., 2025). Interventions such as selective serotonin reuptake inhibitors (SSRIs), behavioral management therapies, and cognitive behavioral therapy have been used to address attention-related difficulties in individuals with ASD; however, their effectiveness may vary across individuals because of heterogeneity within this population (Sanku et al., 2023). As an emerging technology, VR provides a new approach to attention training for individuals with ASD. Keywords related to VR-based attention interventions in ASD include "attention" and "joint attention."

Within this context, VR-based interventions for individuals with ASD can be categorized into individual attention training and joint attention training, depending on whether attention and interest are shared with others. Individual attention, in contrast to joint attention, emphasizes independent and non-shared attentional engagement.

In research on individual attention training, Sanku et al. (2023) developed the Virtual Reality Physiological Data Analysis (VR-PDA) framework, which integrates eye-tracking and physiological data monitoring in an immersive virtual classroom. By comparing four training strategies—scoring, noise, red halo, and object transparency—the study found that auditory-feedback-based noise training was particularly effective in improving attention among individuals with ASD, while the red halo strategy showed specific effects in the ASD group. A related study by Razzak et al. (2025) further indicated that heart rate and electrodermal activity may serve as sensitive physiological markers of attentional changes, suggesting that VR combined with multimodal physiological data may support personalized attention interventions.

Joint attention (JA) refers to the process by which two individuals share attention and interest toward a specific object or event, typically through eye contact, pointing gestures, or other verbal and nonverbal cues (Zhang et al., 2025). Amat et al. (2021) developed InViRS, an interactive VR system designed to train gaze sharing and gaze following in

children with ASD through virtual characters, game-based tasks, and real-time eye tracking. Similarly, Shahab et al. (2022) integrated a social robot, VR, and virtual musical instrument training to develop Virtual Reality Robots (V2R), which trained joint attention through gaze-following tasks. These studies suggest that targeted VR-based training may support both individual attention and joint attention abilities in children with ASD.

4.5 Daily Adaptive Skills Training

Because of social communication deficits, executive function difficulties, and limited targeted training, individuals with ASD often experience challenges in daily living skills, such as independent living, daily task performance, and social adaptation (Abdel Ghafar et al., 2025). VR-based dynamic training may help individuals with ASD transfer acquired skills to real-world social environments (Toma et al., 2024). Keywords related to daily adaptive skills training include "skill," such as "adaptive skill" and "daily life skill."

Yan et al. (2025) developed a multi-scenario immersive VR training system based on the SteamVR platform for children and adolescents with high-functioning ASD. The system included four everyday scenarios—subway, home, supermarket, and amusement park—that reflected common life situations in Chinese society. The training involved 36 tasks, including subway use, shopping, hazard identification, and navigation, and participants completed two rounds of training, with the second round emphasizing speed and accuracy. After an average of 8 weeks of training, qualitative feedback indicated improvements in social interaction, emotion regulation, repetitive behaviors, attention, and daily living skills, suggesting the feasibility of VR-based life skills training for real-world transfer.

In addition to general daily living scenarios, some studies have examined VR interventions for specific life situations. Miller et al. (2020) designed a VR-based air travel training program for five children with ASD using an iPhone X and Google Cardboard. The program simulated airport procedures such as check-in, security screening, and boarding. After three weekly VR training sessions and one real-world practice session at San Diego International Airport, all participants showed improvements in air travel skills and successfully completed airport procedures independently in the real-world setting. This preliminary study provides a useful reference for applying VR training to other specific life scenarios.

4.6 Vocational Preparation and Interview Training

Job interviews are a common pathway to obtaining quality employment. However, for individuals with ASD who experience significant social difficulties, interviews may become a barrier to employment, making the improvement of interview performance particularly important for this population (Smith et al., 2014). With advantages such as repeatable training, real-time feedback, and personalized settings, VR technology provides useful conditions for vocational preparation and interview training for individuals with ASD. Keywords related to this area include "employment" and "job interviews."

SIMmersion, LLC collaborated with experts from academia and vocational training to develop Virtual Reality Job Interview Training (VR-JIT), a VR-based program designed primarily for adolescents and adults with ASD, particularly transition-age youth moving from high school to early employment. In VR-JIT, participants complete simulated job interviews with a virtual interviewer whose responses change dynamically according to their performance. Studies have reported that VR-JIT may improve job interview performance, professional communication, teamwork, relationship-building skills, and self-efficacy among transition-age youth and adults with ASD (Genova et al., 2021; Smith et al., 2014).

Kumazaki et al. (2022) developed a group-based online job interview training program using virtual robots, in which participants with ASD practiced mock interviews through role-playing as candidates, interviewers, and evaluators. After 5 weeks of training, participants showed improvements in self-confidence, motivation, understanding of the interviewer's perspective, verbal and nonverbal skills, and overall interview performance. Together, these studies suggest that VR-based mock interview training may support vocational preparation and interview-related skills in individuals with ASD.

4.7 Training for Co-occurring Conditions: Specific Phobia

In addition to the barriers discussed above, individuals with ASD often experience co-occurring conditions, among which specific phobias are relatively common (Lydon et al., 2015).

To address specific fears and anxiety in individuals with ASD, Newcastle University developed an intervention program called Blue Room (Newcastle University, 2019). Blue Room uses a 360° immersive environment to project computer-generated virtual scenes onto the walls or ceiling, while therapists control scene parameters, such as stimulus intensity, distance, and number, in real time through a tablet. The program integrates cognitive behavioral therapy (CBT) with graded exposure, gradually progressing from low-anxiety scenarios to more challenging situations. Therapists also guide participants in applying CBT techniques, including relaxation training, cognitive restructuring, and coping strategies. Existing studies have reported positive effects of Blue Room on anxiety reduction, target behavior improvement, and real-world functioning in both a randomized controlled feasibility trial involving children with ASD aged 8–14 years and a pilot study involving autistic adults aged 18–57 years (Maskey et al., 2019a, 2019b). These findings suggest that VR-assisted CBT may be a promising approach for addressing specific phobias in individuals with ASD.

5. Advantages and Limitations of VR Autism Intervention

As an emerging interactive technology, VR has been increasingly applied in ASD rehabilitation interventions in recent years. By providing controlled and realistic training environments that can be adapted to participants' individual characteristics and abilities, VR may enhance the ecological validity of intervention training (Mesa-Gresa et al., 2018). Overall, VR shows several advantages and potential applications in ASD rehabilitation. First, VR can simulate real-life scenarios, allow real-time adjustments, and provide repeatable training, thereby creating a relatively safe and low-risk environment for participants to practice various skills (Zhang et al., 2022; Ke et al., 2022; Atsalaki & Kazanidis, 2025). Second, VR-supported interventions are often engaging and interactive, which may increase acceptance, participation, and cooperation among individuals with ASD (Gabrielli et al., 2023). In addition, VR systems can integrate physiological feedback and eye-tracking data, enabling more objective recording of participants' responses and providing quantitative support for clinical practice and research (Kim et al., 2024; Chita-Tegmark, 2016). Some studies also suggest that, through targeted scenario design and intervention guidance, skills acquired in VR training may transfer to real-life situations, such as daily communication and job interviews (Zhao et al., 2022; Genova et al., 2021). Taken together, existing empirical studies suggest that VR offers a low-risk, feasible, and practical pathway for intervention training in ASD rehabilitation.

Despite its promise, the application of VR in ASD rehabilitation also faces several limitations. First, VR still has technical constraints, such as delays between head tracking and visual display and limitations in the effective operating range of equipment, which may reduce participants' training experience to some extent (Mesa-Gresa et al., 2018). In addition, some participants may experience adverse reactions, such as motion sickness and fatigue, because of individual differences in sensory sensitivity and cognitive level (Chu et al., 2023). From a research perspective, current empirical studies on VR-based rehabilitation for individuals with ASD are often limited by small sample sizes and short follow-up periods, which restricts the generalizability of the findings (Zhao et al., 2022). Moreover, substantial heterogeneity remains across studies in terms of training protocols, device types, assessment tools, and scenario design, and a unified clinical intervention pathway has not yet been established (Li et al., 2023).

6. Future Development Trends of Virtual Reality in Autism Rehabilitation

To examine future trends in the application of VR in ASD rehabilitation, this section uses keyword cluster analysis and a thematic map based on centrality on the horizontal axis and density on the vertical axis. Centrality reflects the importance of a theme within the overall research field, whereas density indicates the degree of internal development and maturity of that theme. By crossing the horizontal and vertical axes, four types of thematic patterns can be identified, with circle size representing keyword frequency. Specifically, themes in the first quadrant are motor themes, which represent core issues in the field; themes in the second quadrant are niche themes, which are relatively well developed but less central to the overall field; themes in the third quadrant are emerging or declining themes, which have either recently gained attention or are gradually losing prominence; and themes in the fourth quadrant are basic themes, which represent foundational research areas in the field (Si & Hu, 2023).

As shown in the Figure 4, "augmented reality," "technology," "social skills," "interaction," "facial emotion recognition," "children," "eye-tracking," "blink rate," "fixation duration," and "autism spectrum disorder" are core topics in this field. "Artificial," "kinematics," and "motor skills" are peripheral topics. "Behavior," "adults," "therapy," "skill," "machine learning," "immersive virtual reality," and "design" represent emerging or declining topics. In contrast, "employment," "vocational rehabilitation," "rehabilitation," "social cognition," and "attention" are basic themes that constitute the foundational research topics in this field.

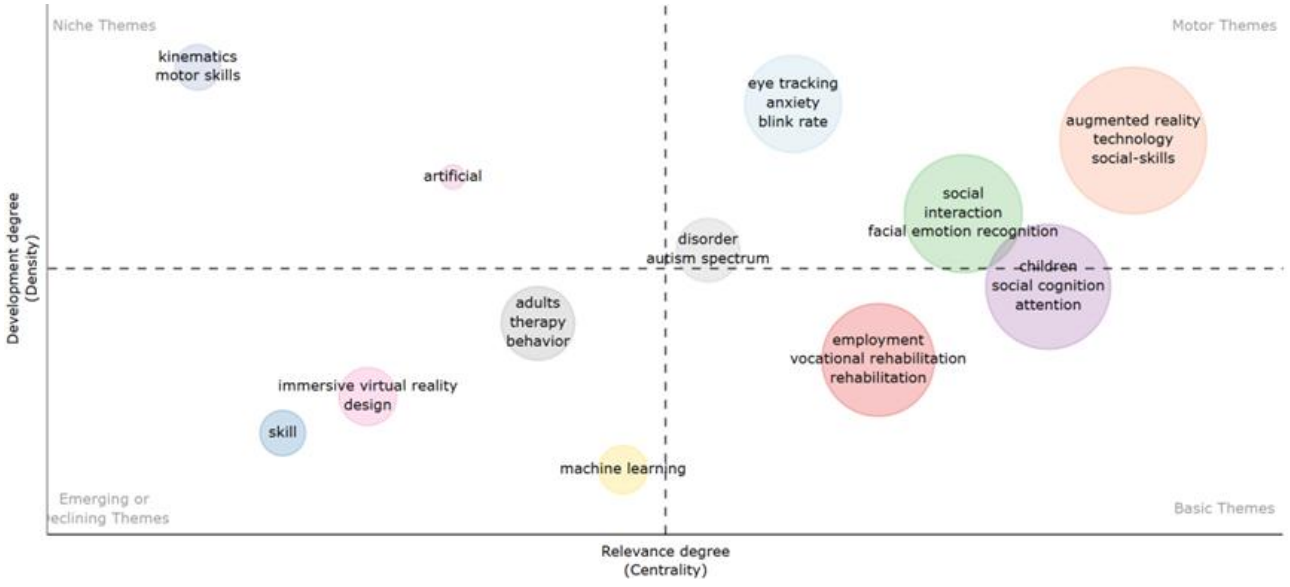

Figure 4. Keyword Thematic Map of Research on Virtual Reality in Autism Spectrum Disorder Rehabilitation from 2000 to 2025

Based on the distribution of high-frequency keywords and the thematic map, research on the application of VR in ASD rehabilitation shows the following trends.

First, VR interventions are becoming increasingly multidimensional and collaborative, with their scope expanding from the core area of social skills to multiple domains, including emotion, attention, and daily living skills. According to the keyword frequency table and thematic map, social skills have consistently remained a central focus of VR interventions for ASD. However, with the development of VR technology, intervention targets have gradually extended beyond social skills. Although research on kinematics and motor skills remains peripheral at present, recent studies have demonstrated the feasibility of using VR to support motor skill interventions for individuals with ASD. For example, Abdel Ghafar et al. (2025) found that VR training may serve as an adjunct to traditional physical therapy for improving postural control in children with ASD.

Second, technological forms are converging and evolving, reflecting a shift from VR toward broader extended reality applications. The continued development of information technology has promoted the use of emerging technologies in ASD rehabilitation. In addition to VR, technologies such as augmented reality (AR) and mixed reality (MR) have provided new perspectives for ASD intervention. Extended reality (XR) refers to a broader technological spectrum that includes VR, AR, and related immersive technologies (Toma et al., 2024). Existing research suggests that XR-based multimodal interactive platforms may help children with ASD improve functional abilities. Future research may therefore move beyond VR alone and further explore the application of integrated multimodal technologies in ASD rehabilitation (Zhao et al., 2024).

Third, artificial intelligence (AI) may further enhance the personalization and adaptability of intervention systems. In recent years, the application of AI in autism rehabilitation has received increasing attention. Existing research suggests that AI has potential in autism assessment and rehabilitation by supporting personalized intervention, outcome monitoring, and progress tracking (Stasolla et al., 2024). When integrated with VR, AI algorithms may enable dynamic difficulty adjustment and personalized feedback, while gamification elements may further enhance engagement and adaptability in intervention design (Mittal et al., 2024). AI can also be combined with machine learning and immersive VR for behavioral assessment, with deep learning techniques potentially improving the accuracy of diagnosis and intervention planning (Capobianco et al., 2025). These developments indicate broad prospects for the deeper integration of VR and AI in future ASD rehabilitation.

Fourth, human-centered design has become increasingly important, with growing attention to user experience and sensory adaptability to reduce adverse reactions. In VR-based interventions for individuals with ASD, intervention specialists and caregivers often adjust intervention content based on data monitoring. In addition, many studies have collected participants' perspectives through questionnaires or interviews on scenario design, participation experience, and adverse reactions (Kim et al., 2024). Some studies have also involved participants in the development of intervention plans, reflecting a stronger emphasis on user-centered and participatory design in future VR-based ASD rehabilitation (Maskey et al., 2019).

Data Availability Statement

The dataset generated and analyzed during the current study is available from the corresponding author upon request.

Conflicts of interest

The authors declare no conflict of interest.

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