



Research Progress of APP Application in Intervention for Children with Autism Spectrum Disorder

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Abstract. This paper combs through the experimental design, intervention goal, intervention environment, and intervention effect of 29 APP applications for autistic children's interventions at home and abroad in the past decade. The results found that: researchers mostly used single-subject research design to explore the application of APP in social skills intervention for preschool children with autism; the interventions were basically implemented in school or family scenarios, and less in community settings; the interventions mainly used APP as a carrier to achieve the intervention goals through the methods of augmentative or alternative communication, visual support, and video modeling; and most of the interventions achieved good results. Accordingly, suggestions are made for the research and practice of APP application in intervention for children with autism in China.

Keywords: app, autism, research progress

1 Introduction

Autism Spectrum Disorder (ASD) is a neuro-developmental disorder that is often accompanied by social communication deficits, repetitive stereotyped behaviors, and narrow and restricted interests ^[1]. According to data released by the Centers for Disease Control and Prevention, the prevalence of Autism Spectrum Disorder (ASD) has climbed from 1 in 150 in 2000 to 1 in 44 in 2021 ^[2], a jump of nearly 240.9% ^[3]. In light of the dramatic rise in prevalence, children with autism have received attention from various industries and public awareness has gradually increased. In recent years, benefiting from the rapid development of the digital age, foreign researchers have developed a large number of APPs for diagnostic assessment, intervention training, data tracking and parental counseling of autistic children based on electronic devices ^[4, 5, 6, 7], which creates a new way of thinking for the education and rehabilitation of

autistic children. APP is short for Application Program, which usually refers to a third-party application program that can be used on mobile terminal devices such as tablets or smartphones to meet the personalized needs of users^[8]. Because it can satisfy users' needs at multiple levels, such as physical/functional level, physiological/psychological level, subjective emotional level, etc.^[9], it has received extensive attention from parents and teachers of autistic children, and has been popularized and applied in actual education. According to the 50th Statistical Report on the Development Status of the Internet in China released by China Internet Network Information Center, as of June 2022, the number of APPs monitored in China's domestic market was as high as 2.32 million. In order to continue to improve the information accessibility services, the Ministry of Industry and Information Technology has carried out accessibility transformation and evaluation for the corresponding APPs, so as to make the intelligent life of special groups warm and barrier-free^[10]. From this, it can be seen that China is also continuously accelerating the construction of information accessibility, keeping close to the application needs of people with disabilities, helping special groups to share the fruits of informationization, and striving to realize the full coverage of information services. However, with the rapid development and promotion of APPs applied to children with autism in China, contradictions and problems have been gradually exposed, such as low professionalism, poor quality, and serious homogenization of APPs, which affect the accuracy of diagnostic assessment and reduce the effectiveness of education and rehabilitation^[11], and even lead to the anxiety of children with autism and their parents and teachers, who are then subjected to unnecessary harm^[12]. Based on the above background, this study systematizes the current research status of APP for autistic children's intervention at home and abroad, with a view to providing references and ideas for relevant research and practice in China.

2 Research Methodology

In the context of the information age, the research and development of APPs applied to the intervention of children with autism at home and abroad have been continuously pushing forward the development of APPs for autistic children and the corresponding research is extended to a deeper and broader direction. In order to better sort out and analyze the new progress of the current research on APP for autism, this study searched the literature on APP for autistic children in the past 10 years, with the specific search date ranging from January 1, 2012, to December 13, 2022. In the CNKI database and Wanfang database, "autism", "app", "APP" were combined. " in the CNKI database and Wanfang database, a total of 4 valid documents in Chinese were retrieved. In EBSCO, Springer, Proquest, Web of Science and Wiley Online Library etc. in five foreign language databases, applying the search terms in the following combinations: (autis* OR asperger OR ASD OR pervasive developmental disorder) AND (APP OR ipad OR technology), using a combination of title, subject, keywords, and abstracts, and limited to peer-reviewed journals, a total of 27 documents were obtained. In order to prevent omissions, a manual search based on reference citations yielded an additional 2 doc-

uments in English. By reading the abstract, introduction, methods, results, and discussion sections of the literature and following the literature exclusion and inclusion criteria described below, a final total of 29 documents were obtained for inclusion in the study.

Literature inclusion criteria: (1) the literature was full-text available empirical journal articles; (2) there was at least one child with autism in the study population who was younger than 18 years old; (3) parents/guardians agreed to the participation of the child with autism; (4) the research topic focused on the use of APP in interventions for children with autism; and (5) the results of the study were clearly defined, the study was well-discussed, and all were supported by detailed data.

Literature exclusion criteria: (1) repetitive literature; (2) articles such as book chapters, news reports, poster campaigns, conference proceedings, patented inventions, etc.; (3) study population other than autism; and (4) methodology of the study was non-empirical.

3 Results

The researcher combed the obtained literature from the intervention target, intervention implementer, intervention environment, intervention time, use of equipment and its applications, experimental design, intervention goals, and intervention effects.

3.1 Spatial characteristics

In terms of spatial distribution, the research in this field in the last decade has been mainly concentrated in the United States (12 articles), after which China (5 articles), New Zealand (3 articles), Australia (3 articles), France (2 articles), the United Kingdom (1 article), Italy (1 article), Singapore (1 article), and Dubai, UAE (1 article) have started to carry out relevant research.

3.2 Subject characteristics

A total of 522 children with autism spectrum disorders were statistically found to be involved in 29 studies, of which 24 (83%) studies reported the gender of 264 subjects; 217 were male (82%); 47 were female (18%). The age range of the subjects was 2-18 years, with the exception of 36 subjects involved in three cross-school studies where age could not be determined based on the reading of the literature, with a high number of subjects aged 2-6 years (preschool stage), totaling 397 (82%); the lowest number of subjects aged 7-12 years (elementary school stage), totaling 21 (4%); and the middle of the range of subjects aged 13-18 years (secondary school stage), totaling 68 (14%).

3.3 Research design

Of the 29 studies included, 22 (76%) were single-subject designs, including 10 multiple-baseline cross-subject designs, 2 multiple-baseline cross-behavioral designs, 3

multiple-detection cross-subject designs, 2 multiple-detection cross-behavioral designs, 2 alternate-treatment designs, and 1 each of an A-B design, an A-B-A-B undo design, and an A-B-C design. Of the other 7 (24%) studies that had a control group, 5 were randomized control designs and 2 were non-randomized control designs.

3.4 Targets of intervention

The main intervention goals included social interaction skills, emotion regulation skills, academic achievement, motor skills, and vocational skills. Among them, the largest number of social interaction skills (17 items) were used as intervention goals, including following instructions (1 item), making requests (4 items), or generalized social interaction, social exchange, and social communication (12 items), and most of the subjects of the interventions (14 items) were children with autism between the ages of 2-6 years (preschool stage). Secondly, there were five studies with academic achievement as the intervention goal, including reading comprehension, literacy, and mathematical arithmetic skills, and the intervention subjects were children with autism aged 6-18 years (school age). In addition, there were 2 studies each with emotion regulation skills and vocational skills as intervention goals. The remaining 3 intervention goals were role-playing, social adaptation, and self-monitoring skills, respectively.

3.5 Intervention programs

The implementer and observer of 13 (44%) study interventions were the researcher himself/herself, a few interventions and observations were done collaboratively or independently by the researcher, school assistants, trainers, parents or teachers, and there were also individual interventions and observations done collaboratively by the researcher and the children's peers, and by the researcher and the parents. It is worth mentioning that, except for the researcher herself, all the participants were required to undergo appropriate training to familiarize themselves with the operation of the equipment and APP, the intervention procedures and related matters.

In terms of intervention settings, with the exception of 3 (10%) studies that did not indicate an intervention setting, 15 (52%) of the studies were conducted in naturalistic scenarios including school classrooms, teachers' studios, libraries, bedrooms at home, and floors at home, and only 11 (38%) of the studies were completed in intervention settings such as individual training rooms, therapy rooms, clinical rooms, laboratories, research centers, hospitals, and so on, that were relatively segregated.

In terms of intervention duration, 5 (17%) studies did not explicitly account for the length of the intervention, 2 (7%) studies reported varying lengths of intervention for different subjects in the same study, 1 (4%) study only accounted for the total number of interventions, and the remaining 21 (72%) studies averaged 12 weeks of intervention, an average frequency of 4 interventions/week, and an average session length of 41 minutes/session.

In terms of intervention devices, most studies (21, 72%) used iPad to run the apps, while a few studies (7, 24%) used devices such as iPhone, iPod touch, Galaxy Note Pro 7, Dell XT2, and NOVA Chat 12TM to run the programs. Regarding the choice of

intervention APP, five studies used Proloquo2Go designed by American researchers, three studies used TOBY Playpad developed by Australian researchers, two studies used Little Raindrop developed by researchers from mainland China, and the other 17 studies chose to use the app according to their intervention objectives. The other 17 studies chose different APPs according to their intervention objectives.

3.6 Effectiveness of interventions

In terms of immediate effects, all 26 studies produced good immediate effects, 1 study presented a mixed effect, and 2 studies had insignificant immediate effects. The mixed effects study specifically reported 3 subjects with good immediate effects and 1 subject with poor immediate effects. The study was an intervention with a peer intervention, and the researchers hypothesized that the reason for this subject's poor immediate effect may have been that the peers in the study were not yet capable of participating in the intervention in terms of personal attributes such as age and socialization level. Fletcher et al. attributed the lack of a favorable immediate effect to the use of the BOSCC scale (Brief observation of social communication change), MCDI scale (MacArthur Communicative Development Inventory), CSBS-DP scale (Communication and Symbolic Behavior Scale- Developmental Profile) and other measurement tools. Developmental Profile and other measurement tools lacked sensitivity. Whitehouse et al.'s study design intervention was for a total of 24 weeks, 7 times per week (1 time per day), each time no less than 20 minutes, but in the actual intervention process the subjects used the application TOBY for an average of 19 minutes per day in the first 12 weeks, and then dropped to 2 minutes per day in the second 12 weeks, and even one subject dropped out due to lack of interest. Subject withdrew from the study due to lack of interest, and the drastic reduction in the length of the intervention may have been one of the factors affecting the immediate effect.

In terms of maintenance effects, most of the studies reported good maintenance results, but one subject had a poor maintenance effect. This subject was from a study by Jing Chen, and after the end of the intervention period, the subject showed a decreasing trend in the number of questions responded to and the level of proficiency, and the researcher did not specify the reason for this. In terms of generalization effects, six studies reported positive generalization effects, while others did not report generalization effects. In terms of social validity, seven studies explicitly reported good social validity.

4 Conclusions

This study combed the research progress in this field at home and abroad in the past ten years by searching for empirical studies applying APP interventions with autism as the subject. The results found that: 1. In terms of spatial characteristics, studies in this field mainly focus on the United States. 2. In terms of subject characteristics, intervention studies mainly focus on male children with autism aged 2-6 years old (preschool stage), and there are fewer studies across multiple school segments. 3. In terms of study de-

sign, most of the single-subject studies were used. 4. In terms of intervention protocols, the majority of these studies were conducted in naturalistic scenarios, where the researcher, teachers, children's parents, and children's peers using iPads running various applications to implement the intervention for about 12 weeks. 5. In terms of intervention goals, the researchers mainly focused on social interaction skills. 6. In terms of intervention effects, most of the studies obtained good immediate and maintenance effects, but only a few of them reported generalization effects and social validity.

5 Revelation

5.1 Research Implications

5.1.1 Subject characteristics.

All subjects were common autism, and there were no studies of children with other autism spectrum disorders such as early infantile autism, Asperger syndrome (AS), Kanner's autism (Kanner), or studies with young children under 2 years of age with autism as subjects. Future studies could be expanded in terms of disorder subtypes and age of autism to explore the effectiveness of APP interventions in a broader group.

It is worth noting that not every study clearly reported the assessment results of subjects' diagnostic information, cognitive level, language, and adaptive behaviors, which would greatly reduce the credibility of the findings, and future researchers should take this as a warning. Furthermore, the subjects were predominantly male, and no study has explored the difference in the effectiveness of apps applied to interventions for children with autism from the perspective of gender differences, which could be investigated by future researchers. Finally, most of the subjects were located in urban areas, and few studies have been extended to remote areas. Comparison of the effects of APP on autism intervention in urban and rural environments is also an area that should be explored in future research.

5.1.2 Research design.

A total of 22 of the 29 studies were single-subject design studies, and only 7 were controlled studies. The single-subject design facilitated in-depth revelation of the relationship between the application of the APP intervention and behavioral changes in individuals with autism, but was unable to discover the general tendency of a large number of subjects and the differences in the means produced by different groups^[13]. Therefore, future research could more extensively use controlled studies to investigate differences in the effectiveness of APP interventions for children with different subtypes of autism, and between children with autism and children with other disorders or children in general.

5.1.3 Targets of intervention.

Most studies aim to intervene in the core social interaction skills of individuals with autism so that they can live and learn better in home and school contexts. The social interaction deficits of individuals with autism severely shackle the achievement of their

goal of complete career development ^[14], therefore, it is necessary to actively explore the effectiveness of various new technologies in intervening their social interaction skills. However, future research could also apply APP to intervene in cognitive-linguistic, motor skills, life adaptation, attention, and other problems and behaviors of children with autism.

5.1.4 Intervention programs.

In terms of intervention implementers, several studies mentioned that parents or teachers were trained in intervention procedures prior to conducting the intervention, but rarely reported on the specific training process and effects, making it impossible to determine whether the intervention process was carried out in accordance with the experimental design. Future researchers need to explicitly report on the content and duration of the training provided to intervention implementers, as well as the results of the evaluation of the effectiveness of the training. In terms of intervention observers, because most of the studies were single-subject designs, they could only rely on people to record data on the occurrence of specific behaviors, but the observers in some of the studies were not professionally trained researchers, but teachers or parents. Although teachers and parents in some of the studies received short-term training from professionals, it is possible that the variability in various aspects such as individual age and level of education may have affected the inter-observer consistency. In future studies, after all observers have learned to use the same behavioral coding and recording system, the researcher should objectively assess the degree of consistency in their recording of results and report the data collection procedures, formulas, and results in the methodology section of the dissertation under the heading of "Inter observer Consistency". In addition, in order to ensure intervention fidelity, it is necessary to document the independent variables and to use the data to illustrate the degree of covariation between the independent variables and the dependent variable, rather than simply assuming that the two exist in a binomial fashion. Specifically, first, an operational definition of the APP intervention is required; second, the dimensions of the APP intervention as a measure of the independent variable are identified; third, the data recording system is specified and the recording media is selected; and finally, observers are trained to use the recording system and to achieve a stable level of consistency.

In terms of intervention environments, most of the studies were conducted in the natural context of family and school, which is conducive to exploring the effects of applying APP to intervene in the abilities of autistic children in daily life in the areas of social interaction, emotion regulation, and vocational skills, and the conclusions of the studies are more easily generalizable, but fewer of them used the community as the intervention environment. Future studies can further investigate the effects of intervention in different community contexts such as shopping malls, supermarkets, amusement parks, and other common community contexts to expand the range of intervention settings. In addition to this, the few studies were conducted in more controlled settings, which can minimize the influence of irrelevant variables on intervention effects, better analyze the functional relationship between the application of APP interventions and the skill levels of the relevant aspects, and also help to better under-

stand the behaviors of children with autism in naturalistic contexts, which in turn can improve their performance.

In terms of intervention duration, the 29 studies ranged from as low as 2 weeks to as high as 36 weeks, the number of weekly interventions ranged from 1 to 7, and the duration of each session ranged from as low as 10 minutes to as high as 240 minutes, which shows that the differences in the duration of the interventions in the various studies varied widely, and the effects of the interventions were also not the same. Future studies can use this as a basis for systematic research to reveal the characteristic relationship between the interaction between the length of intervention and behavior of the APP.

Regarding the choice of intervention devices and APPs, the immediate effects of several studies using ipad as the intervention device were not consistent, and even the studies that also chose Proloquo2Go or TOBY as the intervention APPs showed different immediate effects, which need to be further verified by future researchers. Therefore, future researchers should carefully choose the APP suitable for individual children with autism according to their age, interests and other characteristics, or even individualize and customize the APP, in order to better achieve the best effect of intervention. In addition, there were four studies in which multiple APPs were used and the immediate effects of the interventions were good, but the intervention procedures did not explicitly report the specific operational procedures for the mixed use of multiple APPs, and it is questionable whether the results are credible. It is noteworthy that the ipad and ipod in several studies are actually equivalent to a Speech Generating Device (SGD), which uses APPs as a vehicle to assist individuals with communication disorders to communicate with others. Ipads and ipods have built-in APPs with speech-generating functions that allow users to select or enter text, and output it as speech to communicate with others. The SGDs are built into devices such as ipads and ipods with speech generating features that allow the user to select or input text and output it as speech to compensate for the autistic child's lack of spoken language.

It is important to be wary of the fact that the official website of Autism Speaks, a U.S. autism science organization, publishes hundreds of apps for autism interventions and is still in the process of adding and updating them, but a study by Kim et al. found that the 695 apps published on the site, among them, 95.1% have no direct or indirect evidence to confirm their effectiveness^[15]. In recent years, the number of domestic autism APPs has also been rising, but the APP function is relatively single, mainly to improve the cognitive level of autistic children, and the main user group is the family guardians of autistic children. "Little Raindrop" is the first domestic APP designed by our designer, Liang Xingmei, which is applied to the intervention treatment of autistic children, filling the gap in this field and providing a reference model for the subsequent R&D and design of autism APPs.

5.1.5 Effectiveness of interventions.

The results of the study found that APP intervention can effectively improve the development of children with autism in various aspects such as emotion regulation, academic achievement, motor skills, and vocational skills, but the intervention results were not completely agreed upon. Therefore, future research needs to continue to

explore the applicability of the application of APP to interventions for children with autism and analyze the reasons for the different effects. In addition, researchers should not only report the immediate, maintenance, and generalization effects of the study, but also focus on the social validity of the study to assist subsequent researchers to better understand the context in which the study was conducted. Also, the study could include teachers, parents, and others in the social validity survey to understand the importance, effectiveness, appropriateness, and satisfaction related to the APP intervention as experienced by different populations.

5.2 Practical Implications

First of all, emerging technologies such as Internet of Things, cloud computing, big data, three-dimensional computing and artificial intelligence can be applied to the autism APP to realize technology-enabled learning, create an immersive learning experience for autistic children, and provide personalized learning and accurate services. APP designers can, based on the emerging technologies, collect and analyze the autistic children's learning needs, learning styles, and cognitive characteristics in an all-round way, and customize the exclusive APP for autistic children by using automatic or user settings to adjust the application mode. Based on emerging technologies, based on the comprehensive collection and analysis of autistic children's learning needs, learning styles and cognitive characteristics, the APP designers can adjust the application mode by automatic or user settings, and customize the exclusive APP for autistic children, which can outline the three-dimensional learning landscape of autistic children in terms of the learning time, space, and content, reveal the hidden rules behind a large amount of learning data, and provide dynamic and timely visualized feedback on their learning. Through comprehensive recording, real-time tracking and monitoring of autistic children's learning behaviors, we can predict their future learning trends, identify problems in a timely manner and provide effective interventions to achieve effective learning ^[16]. At the same time, since most autistic children have abnormal senses, VR, AR, MR and other three-dimensional computer technology can be used to generate realistic scenes with multi-sensory stimulation, realizing the combination of reality and reality, real-time interaction, reducing the difficulty of learning, enhancing the fun, and improving the motivation of autistic children to learn.

Second, a comprehensive intervention model that combines APP intervention with other intervention methods is utilized to improve the effectiveness of intervention for children with ASD. Comprehensive treatment models are based on a certain theoretical framework, based on the developmental characteristics and core deficits of each child, systematically using a variety of specific intervention techniques to improve the overall development of children with ASD ^[17]. Children with ASD often have multifaceted impairments and need to develop multiple abilities at the same time, and the different abilities are related to each other, so it has become an inevitable trend to use a variety of specific intervention techniques to provide comprehensive, integrated and systematic interventions for children with ASD. Applied APP interventions are mainly realized through Augmentative and alternative communication (AAC), Visual supports (VS) and Video modeling (VM), which are all specific intervention techniques with evi-

dence-based practice. Specific intervention techniques that are based on evidence-based practice and have been shown to be effective ^[18]. Therefore, therapists, teachers, and parents can also try to combine APP intervention with other proven intervention methods such as music-mediated intervention (MMI), sensory integration (SI), and social narratives (SN) to achieve a comprehensive intervention.

Again, parents and peers are encouraged to intervene in the intervention, and the advantageous role of parents and peers in the intervention of autistic children is utilized. Problems such as high cost, time investment, distance, and difficulty in obtaining effective opportunities for ongoing professional intervention bring greater pressure to parents of children with autism ^[19], and parental intervention can alleviate these problems to a certain extent. Cheng et al. used meta-analysis to integrate and analyze data from 51 studies on parental intervention for children with autism, and found that parental intervention not only has a positive effect on the development of social skills, life skills, and language for children with autism, but also increases parental involvement, reduces psychological and economic pressure, and can even be the main intervention for children with autism who have difficulty in gaining access to professional services. Children with autism who have difficulty in accessing professional services, but the prerequisite for this approach is to carry out appropriate parent training ^[20]. Liu Qi et al. analyzed 21 studies on parental intervention in autism from mainland China, Hong Kong, and Taiwan, and showed that parental intervention is an effective complement to intervention for children with autism, but more than half (14/21) of the studies hindered its further use in China due to the lack of solid theoretical foundations, and specific implementation manuals ^[21]. Of the 29 studies included in this study, 7 were parental intervention studies, and only 1 study did not achieve good even though it may be due to the lack of sensitivity of the measurement tool. Therefore, the effectiveness of parent-intervention APP interventions for children with autism should be fully recognized, and the quality of parent training should be paid attention to in order to improve the fidelity of the intervention. At the same time, a large number of studies have confirmed that peer intervention in autism can also produce positive effects ^[22, 23, 24, 25]. Bene et al. analyzed data from 16 autism interventions using hands and feet as peer interventions, and the results of the study showed that hands and feet interventions helped to develop social communication skills and reduce maladaptive behaviors in autism, and had a good effect on maintenance and generalization ^[26]. Therefore, as a promising and effective intervention model, peer intervention should be applied in naturalistic contexts in schools, families and communities, but the selection of peers needs to be carefully considered, and the age, gender, and personality of peers may affect the effectiveness of the intervention.

Finally, APP intervention should be applied to life skills and academics to improve the quality of life of children with autism. Currently, the use of APP for autism intervention mainly focuses on the development of social interaction skills, and there are fewer studies in other areas, but children with autism need to develop more than that, and the various abilities are related to each other. Wang et al. analyzed the data of 21 studies, and the results showed that there is a significant correlation between the social skills of children with autism and gross motor skills, but the causal relationship between the two needs to be further verified. The causal relationship needs to be further

verified ^[27]. West analyzed data from nine studies of infants with autism and showed that there were significant correlations between gross motor skills, fine motor skills, and levels of language development ^[28]. Frost et al.'s study also found that children with autism's joint attention and imitation skills predicted the rate of growth of their expressive language ^[29]. It is clear that motor skills, social skills, joint attention and language development levels are inseparable and interdependent, and therefore APP interventions cannot be limited to improving only one aspect of the ability. Therapists, teachers, and parents should continue to explore the effects of APP interventions in multiple aspects of autism skills in order to promote the whole-person development of children with autism.

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