Personalized Intelligent Intervention and Precise Evaluation for Children with Autism Spectrum Disorder

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Abstract: Autism Spectrum Disorder (ASD) is a lifelong neurodevelopmental disorder involving core deficits in interpersonal communication and social interactions. There is a pressing need for educational intervention for children with ASD in the field of special education. This study aims at the fundamental problems facing educational intervention for children with ASD based on human–computer interaction. The technical bottlenecks include individual representation, process intervention, and effectiveness evaluation. The main objectives are to improve the accuracy of individual modeling, establish an exact intervention mechanism, achieve precise evaluation, and enhance the intelligence of educational interventions for children with ASD that are based on human–computer interaction.

Keywords: ASD; Human–computer interaction; Intelligent intervention; Precise evaluation

4 Introduction

Autism spectrum disorder (ASD) refers to a broad range of conditions characterized by challenges with social skills, repetitive behaviors, speech, and nonverbal communication [APA13]. According to the Centers for Disease Control, autism affects an estimated 1 in 54 children in the United States [AP20]. Every child or adult with ASD has unique strengths and challenges, so there is no one-size-fits-all approach to autism treatment and intervention. Research has made clear that high-quality early intervention can improve learning, communication, and social skills, as well as underlying brain development. Early intervention affords the best opportunity to support healthy development and to deliver benefits across the lifespan [Pe12]. Educational intervention is the best way to help children with ASD and improve their social interaction abilities. Researchers worldwide are making efforts to help children with ASD, using different technologies. There is evidence that interventions based on human–computer interaction (HCI) offer a novel and effective approach to helping children with ASD [Cé19].

In China, there is a pressing need in the field of special education for educational intervention for children with ASD. This study focuses on the fundamental problems

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with educational intervention based on HCI for children with ASD. The technical bottleneck relates to issues of individual representation, process intervention, and effectiveness evaluation. To this end, our study has three goals:

- To explore the method of understanding the cognitive and affective states of children during interventions in order to model individuals dynamically.
- To design well-structured learning activities and establish an intelligent intervention mechanism adaptable to individuals in order to improve the performance of interventions.
- To develop a hybrid assessment framework of local and global levels to evaluate the effectiveness of interventions comprehensively.

5 The proposed method

The effectiveness of educational interventions depends on three factors: (1) ***the individual representation of learners***, necessary to establish precise models of children with ASD, which is the premise of any effective intervention; (2) ***the process intervention of educators,*** to create systematic learning activities, which is key to any effective intervention; and (3) ***the evaluation of the effectiveness of interventions***, to develop a precise evaluative framework, which is the basis of verifying the effectiveness of interventions. The typical workflow of an educational intervention based on HCI for children with ASD is shown in Fig1.

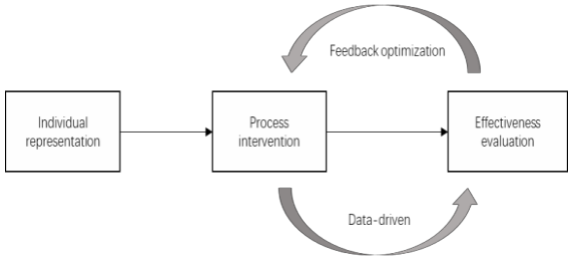

Fig.1: Typical workflow of educational intervention for children with ASD

5.1 Individual representation

There are great differences among individual children with ASD, and the traditional learner model lacks a description of cognitive and affective states. As a result, the accuracy of personal representations of children with ASD cannot be guaranteed. In order to solve this problem, we have proposed a cognition-affect model (see Fig. 2) to analyze the affective states of children based on valence, arousal, and attention; we then infer the

cognitive and affective states on the basis of the current affective state and learning progress, which can comprehensively reflect each child's attention level and emergent behaviors [Ch14]. We have developed a series of techniques for acquiring and recognizing multimodal sensory information of children with ASD. These techniques center on sensing and recognizing human behavior, including head-pose and eye-gaze estimation, facial expression recognition, multicamera surveillance, and use of a large multitouch server for gesture detection. The proposed head-pose estimation is both robust and efficient, based on a method of facial feature detection and tracking from a monocular image series to sense the child's head direction. An efficient eye-gaze estimation method has been developed to determine precisely the focus of a child's attention, freeing the child from physical contact with intrusive equipment. A novel cognitive and affective state detection method facilitates understanding of the child's specific responses to the interactive scenario and thus forms the basis of virtual characters' ability to react to the child's behaviors.

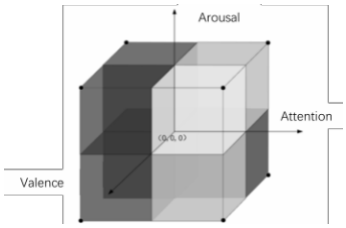

Fig. 2: Three-dimensional cognitive and affective model

5.2 Process intervention

The developmental trajectory of children with ASD is complex and diverse, involving several social interaction learning stages, multiple scenarios, and a complex intervention process. The current single-learning-activity mode and fixed-intervention methods are difficult to apply.

A personalized learning scheme specific to individual needs is very important. While the various theories of psychological functioning in the field of child development have something to offer in terms of understanding the cognitive development of children in general and the deficits associated with autism in particular, individually they are unlikely to provide a full explanation of autism deficits and are therefore unlikely to provide a sufficient basis for learning scenarios for social engagement. We have therefore used three key theories of child development to act as a framework for this research, relating to theory of mind, executive functioning, and central coherence. On the basis of the theoretical framework, three stages of learning activity were presented, namely, mirroring, interaction, and communication. Furthermore, an intelligent intervention system for children with ASD was developed on the basis of a Pivotal Response Treatment (PRT) model that could collect the facial expressions and gaze patterns of

the children during the intervention (see Fig. 3). In addition, the children's emotional states and learning interest were accurately monitored and analyzed in real time; child-centered intervention improves their ability to respond to multiple cues and increases the motivation for social communication, self-initiation, self-management, and empathy.

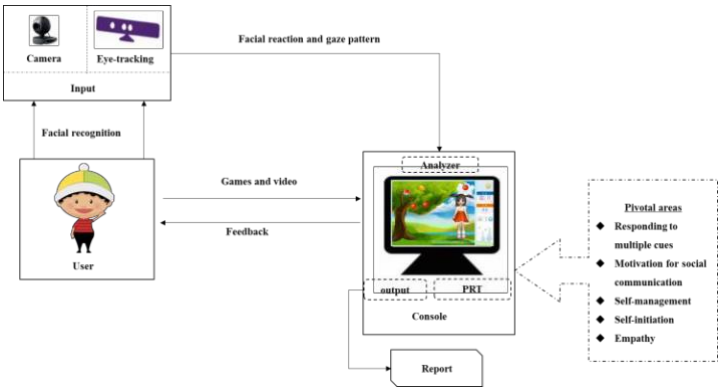

Fig. 3: Intelligent intervention for children with ASD based on the PRT model

5.3 Evaluation of effectiveness

The ability of children with ASD to interact socially is reflected in a complex system of indicators involving behavior, language, and emotion. The evaluation of an intervention's effectiveness is usually obtained by a questionnaire survey and observation of behavior by experts; evaluative results acquired in this way lack objectivity and precision. Therefore, we present a quantitative evaluation method of educational interventions that combines global and local level approaches. On the basis of a model of autistic children and learning goals, empirical research is conducted by combining the use of quantitative assessment technology for autistic children's ability at the local level and a qualitative evaluation framework at the global level, which helps to evaluate the effectiveness and scientific validity of the intervention, as shown in Fig.4.

- **Local level** objectives are those that correspond to specific developmental objectives, such as increasing a child's joint-attention skills (attention and duration of decision making). The learning outcomes at the micro level are evaluated through task-oriented measures within the learning environment, using pre- and post-test metrics; these are associated with each individual learning activity. Technologies such as head-pose estimation and gaze tracking are used to measure social cues.
- **Global level** objectives are those that refer to a developmental change in a child's skills and the ability to generalize those skills to novel situations. We use established metrics in combination with qualitative measures, such as interviews with teachers and parents.

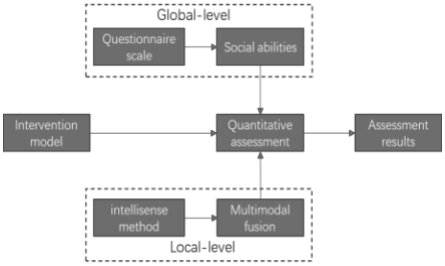

Fig. 4: Quantitative evaluation method of educational intervention

6 Preliminary results & conclusions

We have tested the system with both live video sequences and publicly available face databases, and demonstrated the usefulness of the system via interactive scenarios of engagement studies. The evaluation studies were carried out with small groups of typically developing children and children with autism aged from 5 to 7, with inputs from expert practitioners. For example, one study was conducted in a special school for

20 children with high functioning autism. Each child completed an average of 20 minutes of social engagement training per day, five times a week, for six months. The training activities were adjusted gradually according to each child's progress.

The system has the ability to operate in a natural environment to estimate a user's head pose and gaze direction while also detecting the user's expression. The proposed approach is fully automatic and computationally efficient, which makes it highly appropriate for a real-time system. Children's expressions can be recognized, reflecting their affective state in interactive scenarios. The recognition method proposed is based on the Expression Intensity Ranking Convolutional Neural Networks (EIR-CNN) and deep feature definitions.

The approach frees the user from physical contact with any intrusive equipment. Furthermore, the system supports multicamera surveillance. The functionality of multicamera surveillance allows the user to act freely in an area of large range and to interact with virtual scenarios in a natural manner. It requires only inexpensive and commonly used equipment, which makes the system cost-effective and accessible.

Experimental results indicate that our system can accurately estimate a user's head pose and detect the user's eye gaze with a correctness rate of 96%. An expression-recognition test was performed with a CK+ database and live videos, and the rates for recognition were 91.5% and 87.3%, respectively. The results obtained suggest that the methods have strong potential as alternative methods for sensing human behavior and providing appropriate support. In addition, the study evaluating children with ASD using computer games with this system shows that the computer games designed have great potential in

the field of special education as an evaluative tool to clarify difficulties associated with autism [Ch19].

The successful recognition of cognitive and affective states forms the basis of this engagement study. These cognitive and affective states provide solid criteria for assessing whether and how closely a child is engaged with a virtual scenario. Given the observations from a series of engagement studies with children, we can conclude that:

- Our system enables real-time and reliable recognition of a user's cognitive and affective states.
- The children are engaged with the system and interact with virtual characters.
- Children are more engaged in social communication after six months of engagement training.

The system has strong potential to help children with difficulties to improve their ability to interact socially. In future, we will further verify the effectiveness of the intervention methods and explore the potential application of artificial intelligence in special education.

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