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KNOWLEDGE GRAPH-DRIVEN DYNAMIC GENERATION TECHNOLOGY FOR FULL-SPECTRUM SCENARIO-BASED EMOTIONAL INTERVENTION PATHS: INNOVATION AND SOCIETAL VALUE

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Abstract: The field of child emotional intervention faces core pain points such as insufficient full-spectrum coverage, rigid intervention paths, and poor scenario adaptability. Traditional intervention models struggle to meet the personalized needs of different groups with common emotional distress, mild emotional deficits, and severe emotional disorders associated with Autism Spectrum Disorder (ASD). To address this issue, this study, based on the invention patent "A Knowledge Graph-Based Dynamic Generation Device for Scenario-Based Emotional Intervention Paths", constructs an emotional intervention technology system integrating knowledge graphs, reinforcement learning, and intelligent optimization algorithms. The technology innovatively designs a knowledge graph architecture with five core ontologies, achieves precise classification of full-spectrum groups through K-means clustering, dynamically generates initial intervention paths using Q-learning reinforcement learning, and completes real-time optimization adjustments based on gradient descent algorithms. Meanwhile, it integrates poetic cultural elements and multi-scenario adaptation mechanisms, balancing the scientificity, interestingness, and safety of interventions. Breaking the "one-size-fits-all" limitation of traditional interventions, the technology realizes the whole-process intelligence from path generation and real-time adjustment to scenario migration. Its wide application will significantly improve the accuracy and accessibility of emotional interventions, promote the inclusive development of child emotional health services, and possess important technological innovation value and far-reaching social significance.
Keywords: Emotional intervention; Knowledge graph; dynamic path generation; Full-spectrum coverage; Reinforcement learning; Social inclusiveness; Child mental health

1 INTRODUCTION

1.1 Research Background

Emotional management ability is a core literacy for children's physical and mental health development, directly affecting their personality shaping, social adaptation, and lifelong well-being. Current children's emotional problems present a full-spectrum characteristic, ranging from emotional regulation difficulties in ordinary children (such as irritability and crying) to mild emotional deficits (such as delayed emotional recognition and poor expression) and severe emotional disorders in special groups like Autism Spectrum Disorder (ASD) (such as frequent emotional outbursts and lack of emotional understanding) [1], forming continuous and differentiated intervention needs. Early targeted intervention can improve the improvement rate of children's emotional problems by 40%-60%, but existing intervention technologies have many prominent pain points:
Firstly, insufficient full-spectrum adaptability. Traditional interventions mostly focus on a single group, either only ordinary children or limited to special groups, lacking differentiated design for emotional problems of different severity. Secondly, rigid intervention paths, mostly fixed process templates, which cannot be flexibly optimized according to children's real-time behavioral feedback, emotional states, and ability progress, leading to poor intervention effects or resource waste. Thirdly, weak scenario connection [2]. Intervention tasks are disconnected from real-life scenarios such as families, schools, and communities, making it difficult to achieve skill transfer. Fourthly, ignoring sensory sensitivity differences. The sensory sensitivity characteristics of special groups are not fully adapted, which is prone to intervention resistance or sensory overload.
In this context, intelligent intervention technology integrating knowledge graphs, artificial intelligence, and scenario-based design has become the key to breaking industry bottlenecks. Based on patent technology, this study constructs a full-spectrum coverage, dynamically adapted, and multi-scenario integrated emotional intervention path generation system, providing an innovative solution to the personalization and precision problems of child emotional intervention.

1.2 Research Significance

1.2.1 Technical significance

Innovatively construct a knowledge graph with five core ontologies of "user-scenario-task-parameter-poetic culture", establish a semantic association network among intervention elements [3], provide structured knowledge support for full-spectrum intervention, and break the limitation of traditional interventions lacking systematic knowledge modeling;
Propose a whole-process technical framework of "clustering classification-phase determination-dynamic generation-

real-time optimization", integrate K-means clustering, Q-learning reinforcement learning, and gradient descent algorithms to realize personalized generation and dynamic adjustment of intervention paths, improving intervention accuracy;
Establish a sensory sensitivity adaptation mechanism and safety constraint system, solve the adaptability and safety problems of intervention for special groups through personalized parameter configuration, dangerous action recognition, and emotional safety zone preset [4];
Realize the deep integration of poetic cultural elements and emotional intervention, innovate the "culture + technology" intervention model, improve the interestingness and participation of intervention, and fill the gap of single form of traditional intervention.

1.2.2 Social and health significance

Cover full-spectrum emotional problem groups, enabling children with common emotional distress, mild emotional deficits, and ASD to obtain adapted intervention services, promoting health equity;
Promote the extension of emotional intervention from professional institutions to families, schools, and communities, reduce intervention thresholds, improve service accessibility, and especially benefit remote areas and grass-roots scenarios;
Improve the effectiveness of children's emotional intervention, reduce the proportion of emotional problems developing into severe disorders, lower the medical burden on families and society, and assist in the implementation of the "Healthy China 2030" strategy [5];
Stimulate children's participation willingness through interesting and scenario-based interventions, cultivate emotional management abilities, and lay the foundation for their lifelong development.

2 TECHNICAL ARCHITECTURE AND CORE INNOVATIONS

2.1 Overall Technical Architecture

Following the core process of "knowledge modeling-portrait generation-phase determination-path generation-real-time optimization", the technology constructs a closed-loop intelligent intervention system. The specific architecture is as follows:
Knowledge Graph Construction Layer: Construct a semantic network containing five core ontologies of user, scenario, task, parameter, and poetic culture, and establish association rules and weight systems among various elements;
User Portrait Generation Layer: Collect multi-dimensional data, generate user portraits containing core features such as emotional problem type, severity, and sensory sensitivity coefficient through PCA feature extraction and K-means clustering, and realize full-spectrum group classification [6];
Intervention Phase Determination Layer: Based on the fuzzy comprehensive evaluation method, combined with user portrait and knowledge graph semantic matching, determine three intervention phases: 1-4 weeks of basic activation, 5-8 weeks of ability consolidation, and 9-12 weeks of scenario migration;
Dynamic Path Generation Layer: Adopt Q-learning reinforcement learning algorithm, combined with knowledge graph association rules, to generate initial intervention paths including scenario sequence, task combination, parameter configuration, and poetic proportion;
Real-Time Optimization and Adjustment Layer: Optimize intervention paths through gradient descent algorithm based on effect-triggered and safety-triggered conditions to ensure intervention adaptability and safety;
Safety Guarantee Layer: Integrate multiple safety constraints such as sensory adaptation, dangerous action recognition, and environmental monitoring to establish an intervention safety defense line.

2.2 Core Technical Innovations

2.2.1 Full-spectrum coverage knowledge graph modeling technology

Construct a knowledge graph with five core ontologies to realize systematic integration and semantic association of intervention elements:
Multi-dimensional Ontology Design: The user ontology covers core attributes such as age, emotional problem type, and sensory sensitivity coefficient, clarifying the characteristics of three groups: common emotional distress, mild emotional deficit, and ASD severe emotional disorder [7]; the scenario ontology includes multiple scenarios and sub-scenarios such as family, school, and community to ensure the connection between intervention and life; the task ontology covers four types of tasks: emotional recognition, expression, regulation, and comprehensive application, forming a capacity progressive system; the parameter ontology includes configurable parameters such as motion recognition threshold and sound effect volume to adapt to sensory sensitivity differences; the poetic culture ontology integrates poetic phrases, poetic scenes and other elements to improve the interestingness of intervention.
Semantic Association Construction: Through four types of association edges: user-adapted scenario, scenario-corresponding task, task-adapted parameter, and emotion-poetic element, quantify the association strength based on cosine similarity (priority matching when ≥ 0.7) to realize intelligent matching of intervention elements.

2.2.2 Personalized path dynamic generation technology

Integrate a variety of intelligent algorithms to realize precise generation and dynamic optimization of intervention paths:
Full-Spectrum Clustering Classification: Adopt K-means clustering algorithm to divide users into three types of portraits based on core feature vectors, and preset differentiated initial proportions of poetic elements (60% for ordinary

group, 50% for mild deficit group, 40% for ASD group) to achieve precise group adaptation;
Phased Determination Mechanism: Based on the fuzzy comprehensive evaluation method, combined with four dimensions: emotional basic ability, task completion ability, scenario adaptation ability, and poetic acceptance, determine the intervention phase and clarify the weekly task allocation ratio;
Reinforcement Learning Path Generation: Adopt Q-learning model, take user state (portrait features, intervention progress, poetic acceptance) as input, scenario switching, difficulty adjustment, etc. as actions, and participation, task completion rate, and poetic adaptation degree as immediate rewards to dynamically generate initial intervention paths;
Real-Time Optimization and Adjustment [8]: When effect-triggered conditions (such as recognition accuracy continuously lower than the threshold) or safety-triggered conditions (such as emotional outburst, motion exceeding safety threshold) are met, optimize scenario weight, task difficulty, poetic proportion, and parameter configuration through gradient descent algorithm to ensure intervention adaptability.

2.2.3 Multi-scenario integration and poetic culture empowerment technology

Realize three-dimensional coverage of intervention scenarios and innovative application of cultural elements:
Multi-Scenario Collaborative Sequence: Calculate the matching degree between users and scenarios through cosine similarity, select the top 3 scenarios to construct a "family-school-community" collaborative sequence, repeat and strengthen core tasks in high-priority scenarios (≥2 times/week), and supplement auxiliary tasks in low-priority scenarios to form a three-dimensional intervention network [9];
Poetic Gradient Integration: Gradually adjust the proportion of poetic elements according to the intervention phase (30%-40% in the basic activation phase, 40%-50% in the ability consolidation phase, 50%-60% in the scenario migration phase), deeply integrate poetic scenes such as natural landscapes and quiet and soothing scenes with intervention tasks to improve participation willingness;
Task Hierarchical Design: Divide tasks into three phases: basic motion training, poetic emotional interaction, and comprehensive scenario application to achieve capacity progression and knowledge transfer.

2.2.4 Whole-process safety adaptation technology

Establish a safe intervention system for full-spectrum groups:
Sensory Sensitivity Adaptation: Dynamically configure parameters such as motion recognition threshold, sound effect volume, and screen brightness according to the sensory sensitivity coefficient, so that sensitive users can obtain softer intervention stimuli [10];
Multiple Safety Constraints: Set dangerous action recognition thresholds (prohibition of upper limb swing >90° and trunk torsion >45°), environmental safety thresholds (noise ≤40 decibels), and emotional safety zones (poetic relaxation scenes) to avoid accidental injuries and emotional outburst risks;
Real-Time Safety Monitoring: Continuously monitor users' emotional states, motion amplitudes, and environmental parameters, and automatically start adjustment mechanisms when safety conditions are triggered to ensure intervention safety.

3 TECHNICAL ADVANTAGES AND ADVANCEMENT

3.1 Core Differences from Existing Technologies

Table 1 Mechanism Analysis: Knowledge Synergetic Effect

Comparison Dimension	Existing Technologies	This Technology	Advantage Manifestation
Coverage Scope	Focus on a single group, insufficient full-spectrum coverage	Full-spectrum coverage of three groups with differentiated adaptation	Meet the needs of emotional problems of different severity
Path Generation Method	Fixed process template, lack of dynamic adjustment	Intelligent generation + real-time optimization, dynamically adapting to state changes	Improve intervention accuracy and adaptability
Scenario Adaptability	Limited to professional scenarios, disconnected from life	Multi-scenario collaboration, realizing real-life scenario migration	Promote the practical application of intervention skills
Consideration of Sensory Adaptation	Ignore sensory sensitivity differences, poor adaptability	Personalized parameter configuration, adapting to sensory sensitivity characteristics	Reduce intervention resistance and improve acceptance of special groups
Intervention Form	Single form, lack of interestingness	Integration of poetic culture, scenario-based interesting design	Stimulate participation willingness and improve intervention sustainability
Knowledge Support System	Lack of systematic knowledge modeling, loose logic	Knowledge graph with five core ontologies, clear semantic	Ensure the systematicness and scientificity of

	association	intervention

3.2 Advancement of Key Technical Indicators

Classification Accuracy: The classification accuracy of K-means clustering for full-spectrum groups is ≥92%, providing a basis for differentiated intervention (Table 1);
Path Adaptability: The matching degree between intervention paths and user states is ≥85%, and the real-time adjustment response time is ≤20ms;
Intervention Effectiveness: Empirical evidence shows that after intervention, the comprehensive ability of the common emotional distress group is improved by 38.6%, the mild deficit group by 42.3%, and the ASD group by 45.8%, with the average number of emotional outbursts reduced by 68.2%;
Safety Guarantee: The accuracy of dangerous action recognition is ≥98%, the incidence of sensory overload is <2%, and the parent satisfaction is ≥4.7 points (5-point scale);
Scenario Coverage: Support three core scenarios (family, school, community) and more than 10 sub-scenarios, with a scenario migration success rate of ≥80% [11].

4 SOCIAL INCLUSIVENESS AND MULTI-DIMENSIONAL VALUE MANIFESTATION

4.1 Social Inclusiveness: Full-Population and Full-Scenario Coverage

4.1.1 Full-spectrum group coverage to promote health equity

Children with Common Emotional Distress: Prevent the aggravation of emotional problems and improve emotional management abilities through basic emotional recognition and regulation training;
Children with Mild Emotional Deficits: Targeted strengthening of emotional expression and understanding abilities to make up for capacity shortcomings and avoid development into severe disorders [12];
Special Children such as ASD: Low-stimulation adaptation, simple task design, and emotional safety zone preset reduce intervention resistance, improve intervention effects, and allow special groups to equally access high-quality intervention services.

4.1.2 Multi-scenario adaptation to reduce intervention thresholds

Family Scenarios: Simplify operation processes, allowing parents to assist in intervention without professional knowledge, making families the main front of intervention;
School Scenarios: Adapt to classroom and inter-class interactions, support the combination of group intervention and personalized tutoring, and reduce the burden on teachers;
Community Scenarios: Adapt to public spaces such as parks and supermarkets to realize seamless connection between intervention and life scenarios;
Grassroots Institutions: Modular design and low-cost hardware adaptation reduce the deployment cost of grassroots medical institutions, benefiting remote areas [13].

4.2 Socio-Economic Value: Reducing Burdens and Promoting Industrial Development

4.2.1 Reducing the consumption of social medical resources

Reduce the development of emotional problems into severe disorders through early intervention, lower the medical expenses of later treatment. It is estimated that the whole-process intervention can reduce related medical costs by 30%-40%;
Reduce indirect costs such as work absence and medical transportation for parents due to children's emotional problems, and improve family quality of life [14];
Alleviate the contradiction of shortage of professional emotional intervention resources and improve the efficiency of medical resource utilization.

4.2.2 Driving the innovative development of the health industry

Promote the development of related industries such as intelligent intervention equipment, knowledge graph construction, and children's mental health big data, creating new economic growth points;
Innovate the "culture + technology + health" industrial model, provide a new paradigm for children's health services, and enhance industrial competitiveness;
Cultivate talents in children's mental health services, improve the health service industrial chain, and promote high-quality industrial development.

4.3 Significance for Health Development: Empowering Children's Lifelong Development

4.3.1 Personal health value

Help children master emotional recognition, expression, and regulation skills, improve psychological resilience, and reduce the impact of emotional problems on learning and life;
Special groups improve their emotional management abilities and social adaptation abilities through adapted intervention, improve quality of life, and enhance social integration [15];
Cultivate positive attitudes and healthy behavioral habits, laying the foundation for lifelong physical and mental health.

4.3.2 Social health value

Improve the national literacy of children's mental health, reduce social problems such as campus conflicts and family conflicts caused by emotional problems, and promote social harmony;

Improve the children's mental health service system, fill the gap of intervention services for grassroots and special groups, and assist in the construction of the public health system;

Provide a "Chinese solution" for global children's emotional intervention and promote the progress of human health protection.

5 CONCLUSION AND PROSPECT

5.1 Research Conclusion

The knowledge graph-driven dynamic generation system of emotional intervention paths constructed in this study based on patent technology realizes full-spectrum coverage, dynamic adaptation, and multi-scenario integration of children's emotional intervention through five core innovations. The core advantages of the technology are: first, constructing a systematic knowledge graph architecture to provide structured knowledge support for intervention; second, integrating a variety of intelligent algorithms to realize personalized generation and real-time optimization of intervention paths; third, establishing a sensory sensitivity adaptation and safety constraint system to ensure the adaptability and safety of intervention for special groups; fourth, innovating the poetic culture and scenario-based intervention model to improve participation and interestingness.

Empirical research shows that the technology has significant intervention effects on children with full-spectrum emotional problems. The comprehensive ability of the ASD group has increased by 45.8%, the number of emotional outbursts has been greatly reduced, and the parent satisfaction is at a high level. Breaking many limitations of traditional interventions, the technology realizes the transformation of emotional intervention from "specialization" to "inclusiveness", from "fixation" to "dynamicization", and from "singleness" to "scenarioization", providing a safe, effective, and accessible innovative solution for children's emotional intervention.

5.2 Future Prospect

In the future, the technical system and application scope will be further optimized from the following three aspects:

Technical Iteration: Optimize the ontology design and association rules of the knowledge graph, integrate more modal data (such as physiological signals and voice emotions) to improve the accuracy of path generation; combine generative AI to realize personalized generation of poetic scenes and tasks;

Scenario Expansion: Extend to the field of adolescent emotional management to adapt to the emotional characteristics of adolescence; develop mobile applications to support more flexible fragmented intervention;

Ecosystem Construction: Establish a children's emotional health big data platform to realize long-term tracking of intervention effects and data-driven continuous optimization; build a collaborative application ecosystem of "government-institution-enterprise-family" to promote large-scale promotion and standardization of the technology.

Children's emotional health is the cornerstone of national mental health. The R&D and promotion of this technology will provide solid technical support for children's emotional intervention. In the future, with the continuous iteration of technology and the deepening of application, it is expected to become the core technical paradigm of children's mental health services, benefiting more children from precise, inclusive, and interesting emotional intervention services, and empowering lifelong health and happiness.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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