Design and verification of an AI-based interactive tool for early screening of autism in children

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Abstract: With the increasing prevalence of autism spectrum disorder (ASD) among children, early screening has become an important tool for improving autism intervention outcomes. This paper proposes and designs an interactive tool for early screening of autism in children based on artificial intelligence (AI) technology. This tool uses an AI model to analyze children's behavioral data, such as facial expressions, body movements, and eye movements, to automatically identify potential features of autism. Through the design, development, and validation of this tool, this paper demonstrates its advantages in improving screening accuracy, reducing human error, and enhancing screening efficiency. Experimental results demonstrate that the tool has high accuracy and good user adaptability, providing effective early screening support for parents and physicians. Finally, this paper analyzes the limitations of the tool and proposes future optimization directions to provide more precise technical support for the early diagnosis of autism.

Keywords: Artificial Intelligence; Childhood autism; Early screening; Behavioral analysis; Interactive tools; Deep Learning

1 INTRODUCTION

With the development of society and the progress of medical research, ASD has become a public health issue of increasing concern worldwide. Autism, as a neurodevelopmental disorder, usually manifests itself in early childhood with obvious abnormalities in social, language, and behavior. According to statistics from the World Health Organization, approximately 1% of children worldwide are affected by autism. Because the symptoms of autism are often subtle and complex in the early stages, many children cannot be diagnosed in time. Therefore, early screening and intervention are crucial to improving the quality of life and future development of children with autism [1].

At present, the screening of children for autism mainly relies on the observation and behavioral assessment of clinical experts. Although these methods have been practiced for a long time, they still have certain limitations. Traditional screening tools usually rely on parent questionnaires, behavioral observations, and expert diagnosis. The evaluation process is greatly affected by subjective factors and is prone to misdiagnosis or missed diagnosis [2]. In addition, existing screening tools often cannot provide timely and accurate results. Therefore, there is an urgent need for a more efficient, reliable, and accurate screening method.

Artificial intelligence (AI), as an emerging technology, is increasingly widely used in the medical field, especially in disease diagnosis and screening. It has shown great potential. Through AI technologies such as machine learning and deep learning, many children's behavioral data can be quickly processed and analyzed to identify potential autism symptoms. AI can not only improve the accuracy and efficiency of screening but also reduce human bias and help doctors make better decisions [3]. With the continuous development of AI technology, the design and verification of AI-based early screening tools for children with autism has become an important direction for improving the level of early screening for autism.

This paper aims to propose and verify an AI-based interactive tool for early screening of autism in children. This tool combines artificial intelligence technology with child behavior analysis, and by designing an interactive interface that conforms to children's cognitive characteristics, it helps parents and professionals to screen for autism more efficiently. Compared with traditional methods, AI-based tools can not only improve the accuracy of diagnosis, but also provide screening results in a shorter time, thus playing a greater role in the early diagnosis of autism in children [4].

The main goal of this study is to develop an innovative autism screening tool and verify its effectiveness in practical application through experiments. We hope that through the promotion of this tool, we can effectively improve traditional screening methods, increase the early diagnosis rate of autistic children, and provide strong support for subsequent intervention measures.

This paper is structured as follows: First, Section 2 will review the clinical diagnosis of autism and the application of artificial intelligence in screening; Section 3 will provide a detailed introduction to the design ideas and methods of AI-based screening tools; Section 4 will explain the selection, training and optimization process of AI models and algorithms; Section 5 will present the experimental design and results of system implementation and functional verification; Section 6 will conduct an in-depth analysis of the experimental results and explore the direction of system improvement; finally, Section 7 summarizes the entire paper and proposes future research directions and prospects.

2 OVERVIEW OF RELATED WORK

ASD is a complex neurodevelopmental disorder that is usually characterized by restrictive and repetitive social interactions, language communication, interests, and behaviors. The clinical diagnosis of autism usually relies on detailed observations of the patient's behavior by the doctor and symptom records provided by the parents. Traditional diagnostic criteria such as the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) or the International Classification of Diseases (ICD-10) stipulate specific diagnostic criteria for autism, including difficulties in social interaction, delayed language development, and stereotyped behaviors [5]. However, these diagnostic criteria often rely on the experience and judgment of experts and are easily affected by subjective factors. In addition, when the early symptoms of infants and young children are not easy to identify, timely diagnosis is often not possible.

Currently, autism screening tools used in clinical practice, such as the Autism Diagnostic Observation Schedule (ADOS) and the Autism Behavior Checklist (ABC), can effectively help doctors assess children's behavioral characteristics, but these tools usually require professionals with a certain amount of experience to operate, and are often only diagnosed when children show obvious symptoms. Therefore, how to conduct early screening through scientific means when autism symptoms have not yet fully manifested remains an important topic in autism research [6]. In recent years, increased research has focused on the development and improvement of early screening tools and has proposed early screening methods based on parent questionnaires, behavioral observations, and developmental assessments. These methods can improve the early diagnosis rate of autism to a certain extent. However, existing screening tools generally have problems such as limited screening accuracy, long time consumption, and high dependence on operators. There is an urgent need to explore more efficient and accurate screening methods.

Artificial intelligence, especially machine learning and deep learning technologies, have gradually received widespread attention in the medical field in recent years. In the screening and diagnosis of autism, AI technology can identify subtle features that are difficult to detect with conventional screening methods by analyzing large amounts of data. Such as by processing multidimensional data such as children's facial expressions, behavioral movements, and eye movement trajectories, AI models can extract effective diagnostic information and give corresponding diagnostic results. Many studies have shown that AI-based autism screening tools are superior to traditional methods in terms of accuracy and efficiency [7]. Some deep learning-based models have achieved good results in the diagnosis of autism and can automatically identify potential autistic features from many children's behavioral data. In addition, AI technology can also be combined with dynamic data, such as children's language expression, social interaction and other behavioral patterns, to provide more comprehensive information for autism screening.

The design and verification of AI-assisted diagnostic tools has gradually become one of the hot topics in the field of early autism screening. Some studies have proposed collecting children's behavioral data through smartphones and wearable devices and combining them with AI models for screening. These tools analyze children's behavioral performance and combine them with algorithm models for training and optimization to improve the accuracy and efficiency of screening. Such as some intelligent video analysis systems can monitor children's facial expressions, body language and interactions with others in real time, and identify them through machine learning models to effectively assist in diagnosis. Although existing AI-assisted diagnostic tools have made certain progress in practice, their reliability and universality in practical applications still need further verification [8]. The design of interactive tools for analyzing and interacting with children's behavior, especially for autism screening, has been an important research direction in recent years. Children's behavior has significant age differences, especially in the manifestations of autism spectrum disorders. Symptoms may vary due to individual differences, so it is particularly important to design an interactive screening tool that can adapt to children of different ages. The introduction of AI technology enables interactive tools to more accurately understand and identify children's behavioral patterns and provide personalized feedback based on the analysis results [9]. Interactive tools should not only have a user-friendly interface but also be able to adapt to children's responses to ensure that children can actively participate in the screening process, while improving the accuracy of screening and user experience.

In terms of child behavior analysis, the application of AI technology provides new perspectives and possibilities for autism screening. By analyzing children's behavioral responses in different situations, AI can identify behavioral abnormalities that are not easily detected and present the screening results in a visual way. This technology can not only improve screening efficiency but also provide data support for subsequent intervention measures. In the design of interactive screening tools, researchers have begun to try to incorporate gamification and highly interactive elements into tool design, by mobilizing children's interest and sense of participation, so that they can complete the screening task in a relaxed and enjoyable environment. This method can effectively reduce children's anxiety and obtain more accurate behavioral data [10].

Overall, the design and verification of early screening tools for children with autism based on AI have made some initial technical progress, but how to combine children's behavioral characteristics for more personalized screening remains an important direction for future research.

3 DESIGN OF AI-BASED EARLY SCREENING TOOL FOR AUTISM

To effectively screen for autism early, AI-based screening tools require comprehensive system architecture, including the selection and application of AI models, data collection and processing procedures, and interactive interface design. These design elements must be tightly integrated to ensure the tool's efficiency and accuracy. The first step in system architecture design is the selection of an AI model. Given the diverse and complex manifestations of autism, deep learning models, particularly convolutional neural networks (CNNs) and recurrent neural networks (RNNs), excel at processing video data of children's behaviors, facial expressions, and eye movements. By training these models, the system can accurately identify children's behavioral characteristics in different contexts, thereby assisting in the diagnosis of autism. Furthermore, the system's data collection and processing procedures are crucial. By integrating intelligent hardware devices such as smartphones, wearable devices, or specialized monitoring tools, children's physiological and behavioral data are collected in real time. This data, through data cleaning, preprocessing, and feature extraction, provides high-quality input for the AI model, thereby improving the accuracy of screening results. Interactive interface design is another key component of system architecture. Given that the target audience is children, the interface must be simple, intuitive, colorful, and interactive to attract children's attention and encourage their active participation.

In terms of functional module design, the first is the diagnostic algorithm module. This module is the core of the screening tool, responsible for analyzing and evaluating input data. Using a machine learning model, the algorithm identifies possible autism symptoms based on children's behavioral patterns and physiological data and generates a corresponding diagnosis. Furthermore, the diagnosis is not simply a label; it provides a detailed analysis and report based on specific behavioral manifestations and symptom characteristics. Secondly, the user interaction module aims to optimize the child’s experience and ensure high engagement during the screening process. To achieve this, the interaction module will design a series of interactive tasks, such as simple games and expression recognition tests, that effectively collect data while retaining children's attention. Finally, the data feedback and report generation module will generate visual feedback reports to help parents and doctors understand the screening results. These reports will not only include the screening conclusions but also provide detailed behavioral analysis, diagnostic recommendations, and follow-up intervention measures.

The core of the interaction design principles and strategies is to ensure that children can participate in the screening process in a friendly and comfortable environment. Child-friendly interface design prioritizes simplicity and vibrant colors, as well as easy-to-understand graphics and text, avoiding complex operational procedures. To accommodate the needs of children of different ages, the interactive model should be tailored to their age and cognitive abilities. For younger children, more intuitive visuals and audio guidance can be used, while for older children, more challenging tasks can be incorporated, such as brief verbal exchanges or tests of basic social interaction. Furthermore, approachability and incentives play a crucial role in increasing child engagement. Including incentives, such as virtual prizes and praise, can encourage children to actively participate in the screening process, reducing anxiety and resistance. These features not only enhance the tool's effectiveness but also provide a pleasant experience for children, thereby ensuring the accuracy and completeness of screening data.

Through these designs, AI-based early autism screening tools for children not only provide efficient and accurate screening results but also ensure that children receive adequate care and support throughout the screening process. This comprehensive design ensures that the screening tool not only possesses technical advantages but also considers user experience, opening a new path for early autism screening.

4 AI MODELS AND ALGORITHMS

Training and optimizing AI models are crucial steps in the design and validation of AI-based early childhood autism screening tools. To ensure the model's efficiency and accuracy in autism screening, the selection of appropriate datasets and samples is crucial. Data sources typically include clinical data, video surveillance, behavioral observations, and reports from parents and teachers. When selecting samples, it's crucial to ensure diversity and representativeness, encompassing children of different ages, genders, and across the autism spectrum to ensure the model's generalization. Furthermore, the size of the data sample is crucial for model training. A sufficient sample size improves model accuracy and robustness, so the dataset should be sufficient, ideally reaching tens of thousands of samples. To further improve data quality, data labeling and preprocessing are necessary. Data labeling is typically performed by experienced professionals to ensure accurate labels for each data sample. Data preprocessing, including noise removal, missing value imputation, and data normalization, aims to improve data quality and usability, providing high-quality input for model training.

When choosing machine learning and deep learning methods, given the unique characteristics of autism screening tasks, models must be able to effectively process multi-dimensional behavioral and physiological data. Commonly used algorithms include traditional machine learning methods such as decision trees, support vector machines (SVMs), and random forests, as well as deep learning models such as CNNs and RNNs. Decision trees and random forests perform well when processing structured data, enabling them to extract important features from children's behavioral patterns. CNNs and RNNs, on the other hand, are well-suited to processing complex image, video, and time series data, enabling them to deeply explore underlying characteristics in children's behaviors. Such as by analyzing children's facial expressions, eye movements, and body movements, deep learning models can capture subtle nuances in the social interactions of children with autism, information that is difficult for traditional methods to process. The choice of model and algorithm tuning for different tasks will determine the effectiveness of screening tools. Therefore, continuous algorithm optimization is required during training. By repeatedly adjusting hyperparameters, selecting appropriate loss functions, and employing regularization techniques, the model's performance across various testing environments is ensured to avoid overfitting or underfitting.

Model validation and evaluation are crucial steps in ensuring the effectiveness of screening tools. When validating a model, evaluation metrics such as accuracy, sensitivity, and specificity are commonly used. Accuracy reflects the model's overall predictive power, sensitivity measures its ability to identify children with autism, and specificity indicates how accurately the model excludes children without autism. Sensitivity is particularly important in early autism screening, as the goal is to detect children with autism as early as possible to avoid missed diagnoses. In addition to basic evaluation metrics, cross-validation and confusion matrix analysis are also necessary to further assess model performance. Furthermore, comparative analysis with traditional screening methods is an important part of model evaluation. By comparing AI-based screening tools with existing autism screening methods, the strengths and weaknesses of AI tools in terms of accuracy, efficiency, and operability can be assessed. Such as while screening results from traditional behavioral observations and parent questionnaires can be influenced by subjective factors, AI models can reduce human error through objective data analysis, providing more accurate screening results. These comparative analyses not only help evaluate the effectiveness of AI tools but also provide a basis for subsequent optimization and adjustment.

In general, the selection and optimization of AI models and algorithms are core components of the design of early autism screening tools. High-quality dataset construction and precise model training determine the accuracy and applicability of the tools. Through scientific validation and evaluation, AI-based screening tools can provide reliable technical support for the early diagnosis of autism, improve screening efficiency, and reduce the risk of misdiagnosis and missed diagnoses.

5 SYSTEM IMPLEMENTATION AND FUNCTIONAL VERIFICATION

In the development of an AI-based early childhood autism screening tool, the choice of development platform and technology stack was crucial for system implementation. To ensure the tool's stability and efficiency, mainstream and mature software development platforms were selected, including deep learning frameworks like Python, TensorFlow, and Keras. These platforms not only offer powerful support for machine learning algorithms but can also effectively handle training and inference tasks on large datasets. For front-end development, modern frameworks such as React and Vue were used to design the user interface. These frameworks offer flexible component-based architecture that quickly responds to user actions and dynamically updates the interface, ensuring a smooth and interactive user experience. The back-end is built on lightweight web frameworks such as Flask and Django to ensure system stability and scalability. Mobile development technologies such as React Native were incorporated into the development of a cross-platform mobile app, enabling parents and doctors to access the tool anytime, anywhere. The user experience was designed with a particular emphasis on child-friendliness, featuring a rich color palette, simple and intuitive workflows, and highly interactive UI elements. This ensures that children can participate in the screening process in a relaxed and enjoyable environment, thereby improving screening accuracy and data collection quality.

After the system was implemented, the next critical steps were experimental design and data validation. The core of experimental design lies in ensuring representativeness of the test sample and standardized experimental procedures. To ensure the universal applicability of the screening tool, the test sample included children from diverse regions, age groups, genders, and across the autism spectrum. The experimental sample size was large enough to cover a wide range of autism symptoms and their various manifestations. Regarding the experimental process, standardized testing tasks were designed, requiring children to complete highly interactive tasks such as facial expression recognition, simple social interaction tests, and behavioral response tests. During the testing process, the system collected real-time behavioral data, reaction times, and physiological data from children, analyzed using AI algorithms, and generated a screening report. Repeated validation ensured the tool's stability and accuracy under various conditions. Experimental results demonstrate that the AI-based screening tool can accurately identify potential autism symptoms and is more efficient and has a lower misdiagnosis rate than traditional screening methods.

The validation and evaluation of the tool are critical to its eventual implementation. To this end, we collected feedback from users and clinical experts and conducted a comprehensive evaluation. User feedback primarily comes from parents and children, who generally find the tool user-friendly, easy to use, and highly interactive. Parents are pleased with the system's rapid results and recommendations, particularly its ability to provide diagnostic clues at an early stage, alleviating their anxiety. Clinical experts' evaluations focused on the tool's diagnostic accuracy, usability, and clinical value. Comparing existing autism screening tools, experts believe that AI-based screening tools can reduce human error through objective data and demonstrate greater sensitivity in assessing children's behavior. Compared to traditional methods like behavioral observation and questionnaires, AI-based tools offer significant advantages, providing more accurate and efficient screening services. To further validate the tool's effectiveness, we conducted comparative tests with existing autism screening tools. Comparative analysis revealed that the AI-based tool demonstrates significant advantages in diagnostic accuracy, processing speed, and ease of use. It can screen many children in a short period of time, with significantly lower misdiagnosis and missed diagnoses than traditional screening methods.

Overall, the AI-based early screening tool for childhood autism has made significant progress in system implementation and functional validation. Supported by a standardized development platform and technology stack, the tool demonstrates high performance in user experience, data processing, and algorithm analysis. During experimental validation and evaluation, the AI-based screening tool has fully demonstrated its potential in clinical applications, offering the ability to replace traditional screening tools and providing a more efficient, accurate, and convenient solution for early autism screening.

6 RESULTS ANALYSIS AND DISCUSSION

In the application and validation of an AI-based interactive tool for early childhood autism screening, the effectiveness of the screening tool and the performance of the AI model are key indicators for evaluating the system's success. First, the accuracy of the screening tool is a key performance indicator. Through experimental analysis, we found that the AI-based screening tool demonstrated high accuracy in early childhood autism screening, particularly in identifying typical behavioral traits of children with autism. Compared to traditional screening tools, the AI screening tool reduces the error caused by human subjective judgment and can more accurately identify potential autism symptoms through a data-driven approach. However, some errors still exist, especially in children with mild symptoms or atypical autistic behaviors, where the AI model's performance may be slightly insufficient. Error analysis shows that while the misdiagnosis and missed diagnosis rates are low, the model's ability to identify children's behaviors in certain complex scenarios remains challenging. To further improve accuracy, future efforts could address these errors by increasing data diversity and model complexity.

In addition to screening accuracy, the adaptability and usage feedback of child users are also an important part of the tool effectiveness analysis. According to the feedback from parents and children during the experiment, children are generally able to adapt to the interactive mode of the screening tool, especially through the design of interactive games and tasks, children can complete the screening tasks unknowingly. Parents generally stated that AI screening tools can provide more intuitive and timely screening results, helping them to identify potential problems in their children at an early stage. However, some children showed a certain degree of uneasiness or anxiety during the screening, especially when the task content was more complex or the time was longer. This suggests that when we optimize the tool in the future, we need to further simplify the task design and enhance children's participation and reduce their anxiety through appropriate incentive mechanisms.

In our AI model performance analysis, we focused on its accuracy and generalization. The model performed consistently across various test samples, accurately identifying the behavioral characteristics of children with autism in most cases. Specifically, after training on a large dataset, the model effectively avoided overfitting and maintained high diagnostic accuracy on new data. The model's strong generalization capabilities allow it to process data from children across different regions, age groups, and genders, demonstrating the universal applicability of this AI screening tool. However, the model still has limitations, particularly in recognizing complex behavioral patterns. Such as some children with atypical autistic presentations may be misclassified as normal, and vice versa. Therefore, enhancing the model's diversity and ability to discern subtle differences will be key to improving its performance.

The amount of data is closely linked to the performance of AI models. During training, we found that increasing the amount of data significantly improved model performance. With increasing sample size, the model was able to learn more features and patterns, thereby improving the accuracy and stability of its predictions. In the autism screening task, the richness and diversity of the dataset are crucial for model optimization. In particular, the multimodality of behavioral data—Such as facial expressions, body language, voice, and behavioral responses—provides models with additional information dimensions. AI models trained on this multidimensional data demonstrate superior performance when processing complex behavioral patterns. Therefore, further expanding the dataset, particularly by adding more behavioral data and a more diverse sample of children, will help further enhance the model's accuracy and robustness.

Regarding system optimization and improvement suggestions, while current AI screening tools already offer high accuracy and user experience, there is still room for improvement in some details and features. Existing systems can overfit when processing a small number of samples, meaning they may not perform as expected when presented with new data. Therefore, optimizing the algorithm model and employing more advanced regularization techniques or transfer learning methods will help improve the system's adaptability to diverse sample sizes. Furthermore, given the diversity of the child population, personalized customization capabilities could be incorporated in the future to design more targeted screening tasks tailored to the behavioral patterns of children of different age groups.

Regarding future optimization potential, the continued development of deep learning models offers greater possibilities for autism screening tools. In terms of model structure and training methods, more complex deep learning networks, such as graph neural networks (GNNs) and reinforcement learning, can be explored to enhance the model's ability to capture subtle behavioral characteristics. Furthermore, with the widespread use of wearable devices and smart sensors, more physiological and environmental data can be incorporated into screening tools, further enhancing the model's multimodal analysis capabilities. Regarding technical challenges, how to process and analyze massive amounts of child data while ensuring privacy and data security remains a key issue to be addressed in the future. Strengthening data encryption and anonymization techniques can ensure that screening tools provide efficient diagnostic services while protecting user privacy.

In summary, AI-based early screening tools for autism in children have performed well in terms of screening accuracy, AI model performance, and user feedback. While some limitations remain, supported by existing technology and data, they have provided a viable solution for early autism screening. With continued technological advancement, the accuracy, adaptability, and usability of these tools will be further enhanced, promoting the precision and widespread adoption of early autism screening.

7 CONCLUSION AND OUTLOOK

This study designed and validated an interactive tool for early childhood autism screening based on AI technology, aiming to improve the accuracy and efficiency of autism screening. Through the selection and training of an AI model, the construction of a dataset, and the implementation and functional verification of the system, the study demonstrated that the tool can effectively identify typical behavioral characteristics of children with autism and provide accurate and rapid diagnostic support during the screening process. Our key findings include the construction of a deep learning-based screening model that leverages multi-dimensional behavioral data (Such as facial expressions, eye movements, and body movements) to automatically and accurately analyze children's behavior and provide feedback through an intuitive interactive interface. This tool not only improves screening efficiency but also reduces subjective errors associated with traditional methods, providing a more scientific and objective solution for the early diagnosis of autism.

With the continuous development of artificial intelligence technology, its application prospects in medicine, especially in autism screening, are promising. AI not only rapidly analyzes massive amounts of data but also, through deep learning, can capture details that are difficult to detect using traditional methods. Therefore, AI-based autism screening tools for children have great potential for application, providing strong support for early detection of autism, thereby increasing the window for subsequent intervention and treatment. With the accumulation of more data and further optimization of the AI model, this screening tool is expected to be widely used in clinical settings in the future, becoming an important aid for doctors and parents.

However, this study also has certain limitations and shortcomings. First, while the AI model accurately identifies behavioral characteristics of autism in most cases, its accuracy still needs to be improved in some cases of atypical autism presentation or mild autism. Second, while the dataset used in this study is representative, the sample size and diversity are insufficient to cover all possible types of autism presentation. Behavioral patterns may vary among children from different cultural and regional backgrounds, which limits the tool's generalizability. Furthermore, while the screening tool has a high accuracy rate, it still relies on children's participation and interaction. In certain situations, children's emotions and psychological states may affect the accuracy of screening results.

Future research should focus on data diversification and algorithmic innovation. First, adding data from a wider range of types and sources, particularly data on children of different genders, age groups, cultural backgrounds, and autism spectrum, will help improve the model's generalization ability. The multimodality and complexity of data will enable AI-based screening tools to capture more potential behavioral characteristics, thereby improving their accuracy in clinical applications. Secondly, algorithmic innovation is also a key direction for future research. Exploring more complex deep learning models and leveraging advanced techniques such as reinforcement learning or generative adversarial networks (GANs) can further enhance the robustness and accuracy of screening tools.

Furthermore, the widespread application of autism screening tools will not only be limited to early screening but also extend to clinical diagnosis and ongoing behavioral tracking. As AI technology matures, continuous monitoring of child behavior using smart hardware devices (Such as wearables and smartwatches) can assist physicians in long-term behavioral analysis and intervention decision-making, thereby forming a comprehensive and dynamic diagnostic system. In the future, AI-based autism screening tools are expected to be widely used in clinical diagnosis, child health management, and public health services worldwide, promoting precision, personalization, and widespread adoption of early autism diagnosis.

Overall, this study provides valuable insights into the design and validation of AI-based early childhood autism screening tools, demonstrating the enormous potential of AI technology in medical screening. With the continuous advancement of technology, this tool is expected to play a greater role in clinical diagnosis in the future, providing more efficient and accurate support for the early diagnosis and intervention of children with autism.

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