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Optimizing Early Detection of Early Childhood Developmental Disorders: The Role of Artificial Intelligence (AI) and Parental Involvement in Effective Interventions

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ABSTRACT

Early detection of developmental anomalies in children is crucial for timely intervention, which can significantly enhance long-term developmental outcomes. This study aims to evaluate the effectiveness of an artificial intelligence (AI)-based detection tool and parental involvement in identifying and managing developmental disorders in children aged 2 to 6 years. A longitudinal research design was employed, involving 300 children exhibiting early signs of developmental disorders and 150 children in a control group. Data were collected through behavioral observation, AI-based analysis of video and audio interactions, and interviews with parents and educators. The findings revealed that the AI tool demonstrated high sensitivity in detecting motor, language, and autism-related disorders. Children who received early interventions showed significant improvements, particularly in motor skills, language development, and social interaction. Parental involvement in the intervention process further accelerated these improvements. This study highlights the potential of AI to enhance early detection and intervention, especially in resource-limited areas, and underscores the importance of engaging parents in the developmental process of their children. These findings contribute to the understanding of how AI can be integrated into early childhood care programs to improve outcomes for children with developmental challenges.

INTRODUCTION

Early childhood development is a very important phase in human life, where the brain develops rapidly and basic skills begin to form. In this period, children experience not only physical development, but also major changes in cognitive, social, and emotional terms (Kuzik et al., 2020; Roslan et al., 2022; Sartika et al., 2021). Along with this rapid development, there are also challenges faced by children, especially those who experience anomalies or disturbances in the developmental process. Developmental disorders in early childhood can vary, ranging from delayed motor and language development, to more complex disorders such as autism spectrum disorder (ASD) and dyslexia (Bhat, 2022; de Lima et al., 2022; Snowling et al., 2019). Identifying and addressing anomalies in early childhood development is essential to ensure that they can grow and develop optimally (Lipkin & Macias, 2019; Weitzman et al., 2017). Some of these disorders can be detected at a very early age, but many parents, educators, and medical professionals still have difficulty recognizing the early signs of the disorder.

Therefore, research on early detection and intervention against child developmental anomalies is very important (Smith, 2019)

Early detection is key in dealing with child developmental anomalies, because the sooner the disorder is detected, the more likely it is to provide effective interventions (Costello, 2016). In recent years, research has shown that early detection in children with developmental disorders can improve their future development (Hadders-Algra, 2021; Majebi et al., 2023). However, although knowledge of the importance of early detection has grown, its application in the field is still limited, especially in developing countries with limited resources (Ginsburg et al., 2020; Murillo & Robles, 2019). The research conducted by Santiago et al. (2020) shows that many developing countries do not have an effective and affordable screening system to detect developmental disorders in children. Some of the factors that affect this include lack of training for medical personnel and educators, limited access to advanced technology for screening, and lack of parental awareness of the importance of early detection. Nonetheless, efforts are being made to address this problem, including through improved education for parents, the development of artificial intelligence (AI)-based screening technology, and increased collaboration between medical personnel, educators, and parents in supporting child development (Liao & Lin, 2017)

The main issues raised in this study are how to improve early detection of child developmental anomalies, as well as how appropriate interventions can help reduce the long-term impact of these disorders. One of the solutions that has been proposed is the use of technology in early detection. Research by (Purnomoasri & Handayani, 2022) shows that AI-based technology can help speed up the detection process of child developmental disorders in a more accurate and efficient way. This technology makes it possible to identify behavior patterns or symptoms that are difficult to detect by humans, making it easier for medical personnel and educators to screen children who are at risk of developmental disorders. On the other hand, parental involvement is also very important in supporting early detection, as they are the parties who interact with children the most. Research by (Georgiou & Theodorou, 2023) shows that parents who have knowledge of the signs of developmental disorders can more quickly recognize problems in their children, so they can immediately seek the necessary help.

One of the approaches proposed in the literature is the development of a standardized, widely applicable screening model. For example, (Liao & Lin, 2017) noted that various screening models developed in developed countries have been shown to be effective in detecting developmental disorders from an early age. However, such models are still not universally applicable, especially in developing countries with limited infrastructure and resources. Therefore, it is necessary to make adjustments to the existing screening model to be more in line with local conditions, both in terms of cost, human resources, and available health infrastructure. The use of technologies such as mobile-based applications or AI-based devices can help improve the accessibility and efficiency of screening, especially in areas that lack adequate medical facilities (Bishop, 2021)

However, despite the various solutions that have been proposed, the gap between research and practice in the field is still quite large. Many developing countries still face major challenges in terms of the implementation of technology for early detection. This is related to factors such as limited access to advanced technology, lack of training for medical personnel and educators, and limited funds to develop and implement effective screening systems.

Santiago et al. (Santiago et al., 2020) emphasizes that although many studies have shown the success of the use of technology in early detection, implementation in developing countries is still limited, and a more practical and affordable approach is needed to be widely applied. Therefore, it is important to conduct further research that can identify solutions that are more appropriate to local conditions and ensure that early detection can be carried out effectively around the world, especially in developing countries (Carter & Stephenson, 2020)

The potential of technology, particularly Artificial Intelligence (AI), to bridge this gap is substantial, yet its application in developing contexts remains critically underexplored. Purnomoasri & Handayani (2022) demonstrated that AI-based tools can analyze behavioral patterns from video and audio data to identify subtle signs of disorders like ASD with high accuracy, often surpassing human observation. However, their research, like much of the current literature, is primarily situated in well-resourced, urban settings. Similarly, Georgiou & Theodorou (2023) developed an AI tool for language disorder identification with promising sensitivity, but its model assumes a level of technological infrastructure and digital literacy seldom found in rural or low-income areas. This creates a significant "application gap," where innovative solutions fail to reach the populations most in need.

Furthermore, the challenges extend beyond mere technology access. Liao & Lin (2017) note that while standardized screening models from developed countries are effective, they often require adaptations to be culturally, linguistically, and economically feasible in different contexts. The direct transfer of these models without localization ignores socioeconomic realities, such as cost constraints and diverse caregiver beliefs about child development. Complementing this, Bishop (2021) emphasizes that even when technology is available, a lack of coordinated training for community health workers and educators severely limits its deployment and effectiveness. This indicates that a purely technological solution is insufficient without a parallel investment in human capacity building and community engagement.

The urgency of addressing this research-practice divide cannot be overstated. In developing countries, delayed detection leads to a cascade of negative outcomes: children face increased risks of academic failure, social exclusion, and lifelong dependency (Carter & Stephenson, 2020). The burden on families and healthcare systems also intensifies, as interventions become more complex, costly, and less effective with age. Therefore, research that not only validates AI tools but also develops integrated, low-cost, and culturally-sensitive implementation models is urgently required.

The primary objective of this study is to develop and validate an integrated early detection framework that leverages artificial intelligence and proactive parental involvement to improve the timely identification of developmental disorders in early childhood within resource-constrained settings. By understanding the challenges and implementing more integrated solutions, this study hopes to make an important contribution to improving the detection and early intervention of early childhood developmental anomalies in various parts of the world. Thus, this research is expected to provide new insights that can be used to formulate more effective policies and strategies in detecting and dealing with child developmental disorders.

METHOD

This study adopted quantitative and qualitative approaches to evaluate the effectiveness of early detection methods for developmental anomalies in early childhood. The methodology integrated data from direct screening of children with developmental disabilities, interviews with parents and educators, and AI-based technology analysis (Purnomoasri & Handayani, 2022).

The study employed an experimental research design with a longitudinal approach to assess changes in children with developmental disorders over time following intervention. Qualitative insights were gathered through in-depth interviews with parents, educators, and medical personnel regarding their perceptions of intervention effectiveness (Georgiou & Theodorou, 2023).

Research occurred in early childhood development centers across regions in Indonesia, focusing on children aged 2-6 years in detection programs. Subjects included 300 children showing early signs of disorders such as motor, language, and autism spectrum disorder (ASD), plus parents, educators, and medical personnel; a control group of 150 normally developing children enabled effectiveness comparisons.

Main instruments comprised standardized screening tools like the Denver Developmental Screening Test (DDST) and Ages and Stages Questionnaires (ASQ), alongside AI technologies for video and audio analysis of interactions (Liao & Lin, 2017). In-depth interviews collected qualitative data on parents' and educators' experiences in identifying disorders and supporting children (Carter & Stephenson, 2020).

Data collection involved direct observation in school and home settings by trained personnel, plus AI analysis of behaviors, voice, and facial expressions. Interviews captured perspectives on recognizing signs and intervention efficacy (Pelham & Fabiano, 2020; Bishop, 2021).

Data analysis used descriptive and inferential statistics for quantitative elements, thematic analysis for qualitative interviews, and machine learning for AI-generated behavioral patterns (Zhang & Lee, 2022). Quantitative results compared intervention and control groups, while qualitative findings explored stakeholder interactions and perceived effectiveness (Nunes & Gibson, 2020).

Study results were presented in reports with key findings, discussions, tables, graphs, and narratives on challenges faced by parents and educators (Bax & Gorter, 2020).

RESULTS AND DISCUSSION

The results of this study aim to evaluate the effectiveness of early detection of developmental disorders in early childhood using an artificial intelligence (AI)-based technology approach and parental involvement in the intervention process. Data collection was conducted over 12 months at several early childhood development centers in Indonesia, involving 300 children who showed signs of developmental impairment and 150 children in a control group who showed normal development. This study revealed a number of important findings related to early detection, intervention effectiveness, and the impact of technology and parental involvement in supporting the development of children who are detected to have disorders.

Early Detection Using AI-Based Technology

One of the main objectives of this study is to measure the effectiveness of artificial intelligence (AI)-based technology in detecting developmental disorders in early childhood. The use of this technology allows for the analysis of children's behavior through video and sound recordings collected in their interactions with parents and educators. The AI technologies used in the study, such as machine learning algorithms and facial expression analysis, have been shown to have very high accuracy in detecting signs of developmental disorders. Based on data analysis, the AI model successfully identified behavioral patterns that indicate potential developmental disorders in children that have not been detected through traditional screening methods.

The AI model developed for this study has a sensitivity of 92% in detecting motor and language development disorders, and 88% in detecting autism spectrum disorder (ASD). The data obtained through this tool is very helpful in accelerating the process of identifying children who are at risk of developmental disorders. By utilizing this technology, children who were previously undetected with disorders, can immediately get the necessary medical attention and education. This finding is in line with the results of previous research that showed that AI technology can improve efficiency and accuracy in the early detection of developmental disorders (Georgiou & Theodorou, 2023)

Comparison of Screening Results with Control Groups

In a control group of 150 children who showed normal development, screening results showed that most of these children showed no symptoms of developmental disorders. However, in some cases, even if the children do not show significant developmental impairments, there are some early signs of delays in language development that are only detected through behavioral analysis using AI technology. This suggests that even in children who appear to be developing normally, early detection through technology can help identify developmental delays that may not be seen with traditional screening.

In contrast, in the group of children who were detected to have developmental disorders, the data showed that 75% of them showed significant improvements in motor and social aspects after getting early intervention. This shows that early detection carried out through AI-based technology allows children to immediately receive interventions that can improve their development, both in terms of motor and social.

The Effectiveness of Early Intervention on Child Development

The results of this study also showed that children who received early intervention based on the results of early detection carried out with AI technology showed better development in various domains, such as motor, language, and social-emotional, compared to children who did not receive early intervention. As many as 80% of children who received the initial intervention showed significant improvements in their motor and language development after six months of the intervention. This is in line with previous findings that early intervention can improve developmental delays in children (Santiago et al., 2020)

Interventions are implemented in a variety of forms, including physical therapy to improve fine and gross motor skills, speech therapy for children with speech delays, and social programs for children who show difficulty interacting with their peers. This approach is not

only focused on hands-on therapy, but also involves parents in the process of monitoring the child's development at home. Interviews with parents show that they feel more prepared and more confident in supporting their child's development after being trained on the signs of developmental disorders and how to provide appropriate support at home (Smith, 2019)

The Role of Parents in Supporting Early Detection and Intervention

Parental involvement in early detection and intervention for developmental disorders has been shown to have a significant impact on children's developmental outcomes. Interviews conducted with parents and educators reveal that parents who are more educated about child development can more quickly recognize signs of developmental disorders and take the necessary steps to seek appropriate interventions. Previous research by Carter & Stephenson (Carter & Stephenson, 2020) also supports these findings, suggesting that parental involvement in the early childhood education process contributes significantly to the success of interventions.

In the group of children who were detected to have developmental disorders, 70% of parents who were actively involved in the intervention process reported faster improvement in their child. Parents who were trained on ways to support a child's development at home, such as providing appropriate language stimulation and engaging the child in games that train motor skills, reported that their children became more responsive to the therapies provided. This suggests that parental involvement in supporting interventions can accelerate the recovery of children with developmental disabilities.

The Influence of Technology on the Effectiveness of Early Detection and Intervention

The results of this study also show that AI-based technology has great potential to increase the effectiveness of early detection and intervention against developmental disorders. In this case, technology not only serves to detect disorders with high accuracy, but also provides data that can be used to tailor intervention approaches that are more suited to the individual needs of the child. AI technology provides advantages in terms of time and cost efficiency, as well as helping medical personnel and educators to make faster and more informed decisions about the intervention steps to take.

Based on the data obtained, 85% of the children who received technology-based interventions showed a significant improvement in their language and motor development within six months. This suggests that the application of technology can improve the success of detection and intervention in early childhood. This is in line with the results of a study by (Zhang & Lee, 2022) which found that AI-based technology can improve the effectiveness of early detection in children at risk of developmental disorders.

The Influence of Social and Economic Factors on Early Detection

In addition to technological factors, social and economic factors also play an important role in the early detection of developmental disorders. This study found that children who come from families with low socioeconomic status tend to have delays in early detection of developmental disorders. Despite this, the children still showed significant improvement after receiving early intervention, with 60% of them showing improved development after six months of therapy. This underscores the importance of providing greater support for families

of low socioeconomic status to ensure that all children, regardless of background, can access the early detection services and interventions they need (Nunes & Gibson, 2020)

Discussion

The results of this study highlight the importance of early detection and intervention in dealing with developmental anomalies in early childhood. The use of artificial intelligence (AI)-based technology to detect early signs of developmental disorders, combined with parental involvement in the intervention process, has proven to be an effective approach in improving children's developmental outcomes. In this section, we will discuss the implications of these findings in the context of the existing literature, explore the challenges faced in the implementation of early detection systems, and assess the potential development of these interventions in various settings.

The Effectiveness of Early Detection Using AI Technology

One of the significant findings of this study is the high accuracy of AI-based tools in detecting developmental disorders in the early stages. As reported, the AI algorithm, which analyzes behavioral data such as facial expressions and vocal patterns, showed a sensitivity of 92% in detecting motor and language disorders, as well as 88% in detecting autism spectrum disorder (ASD). These findings are in line with research by Georgiou & Theodorou (Georgiou & Theodorou, 2023)which shows that AI tools can improve accuracy and efficiency in the early diagnosis of developmental language disorders. Additionally, Purnomoasri & Handayani (Purnomoasri & Handayani, 2022)emphasize the great potential of AI in aiding in the diagnosis of developmental disorders earlier than traditional methods, providing a compelling reason for the adoption of this technology in various clinical settings.

AI's ability to analyze complex behavioral patterns in children, which may be too subtle for human observers to observe, marks a significant advance in developmental screening. For example, AI's ability to identify early signs of delayed speech or repetitive behaviors associated with ASD has major implications for improving early intervention services. Zhang & Lee (Zhang & Lee, 2022) suggest that early identification allows for faster interventions, which can substantially reduce the impact of developmental delays, improving long-term outcomes for children diagnosed with the disorder.

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CONCLUSION

This study investigated the effectiveness of early detection of developmental disorders in early childhood, with a focus on the application of artificial intelligence (AI) and the role of parental involvement in interventions. Key findings show that AI-based detection tools have high accuracy in identifying developmental disorders, with sensitivity reaching 92% for motor and language disorders and 88% for autism spectrum disorder (ASD), allowing for faster and more timely interventions. Parental involvement in the intervention process improved outcomes, as parents who received the training reported faster improvements in their children's motor, language, and social skills. This research contributes to the development of knowledge about the potential of AI in improving early detection and intervention of developmental disorders, especially in resource-constrained areas. In addition, these findings highlight the importance of parental involvement that was often underlooked in previous research. The implications of these findings suggest that integrating AI-based screening tools in early childhood care programs can significantly improve the detection and management of developmental disorders. Further research is expected to explore the application of AI-based interventions in a variety of different cultural and socioeconomic contexts, as well as further investigations into the long-term impact of AI-facilitated early intervention on children's cognitive and social development.

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