How Can a Game-Based Approach Improve the Assessment and Understanding of Autism Spectrum Disorder Across Cognitive and Motor Domains?

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Abstract

This project explores the use of a game-based approach to assess social and motor functions in children with Autism Spectrum Disorder (ASD). During the N-CODE Study Group, we conducted an extensive review to identify gaps in game-based cognitive and emotional assessments, identifying key metrics such as gaze-following, emotion recognition accuracy, reaction time, and motor coordination as potential digital biomarkers for ASD. We also explored a broad range of enabling technologies (mobile-compatible eye-trackers, computer vision models, non-contact motion analysis, and large language models) to evaluate their applicability and integration into a flexible, adaptive assessment framework. The resulting prototype concept leverages immersive storytelling and sensor integration to transform traditional assessment into an engaging and naturalistic experience for users. This report outlines the development rationale, methodological roadmap, and proposed implementation strategy for a modular system designed to support monitoring, longitudinal tracking, and personalised intervention planning for neurodivergent populations.

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition that affects approximately 1 in 160 children globally, with core features including challenges in social communication, restricted interests, and atypical sensory and motor processing (WHO, 2021). Among the most affected domains are social cognition and motor control, which can impact gesture use, reaction time, and overall coordination. Social cognition is a broad term which can be defined as the ability to perceive, interpret, and respond appropriately to social cues (Beaudoin and Beauchamp, 2020). These challenges in social and motor domains often emerge in early childhood, during a critical period of neuroplasticity when timely intervention can have the most profound and lasting impact.

Traditional diagnostic and assessment methods for ASD, such as structured observations (e.g., ADOS) and parent questionnaires, are typically conducted in a hospital or clinical setting. These environments, while controlled, can provoke anxiety or sensory overload in neurodivergent children, leading to atypical responses and masking of natural behaviour. Moreover, such assessments are time-intensive, require specialist training, and often suffer from limited accessibility. These barriers can contribute to delayed diagnosis, increased family stress, and missed opportunities for early, personalised support.

There is growing recognition of the need for more inclusive, engaging, and community-deployable tools that capture the lived experiences and behavioural profiles of children with ASD. Recent advances in adaptive technologies (eye-tracking, facial emotion recognition, and touch-based analytics) present a unique opportunity to develop such tools. When embedded in game-based environments, these technologies can transform assessment into a playful, non-intrusive experience that aligns with children's natural modes of engagement.

This project, conceptualised during the N-CODE Study Group in April 2025, responds directly to these needs. It proposes the development and pilot testing of a digital platform that uses interactive games to assess emotional understanding, joint attention, and motor responsiveness. By combining non-contact behavioural tracking with immersive storytelling and co-designed game mechanics, the platform aims to improve the accuracy, accessibility, and child-friendliness of ASD assessments. It prioritises inclusivity — both in design and in deployment — with the broader goal of shifting neurodevelopmental diagnosis and monitoring from hospital to home and community settings. Through this approach, we aim to contribute to a more equitable, effective, and person-centred model of care.

Description of the Problem

ASD encompasses a wide range of neurodevelopmental differences, typically emerging in early childhood and affecting key domains such as social communication, emotional recognition, and motor coordination. Children with ASD often experience difficulties in interpreting and responding appropriately to emotional cues, such as facial

expressions, tone of voice, or social gestures, which can impact their ability to engage in reciprocal interactions with peers, caregivers, and educators (Forby et al. 2023). These social-cognitive challenges frequently coexist with sensory sensitivities (e.g., to noise, light, or touch) and motor planning difficulties, making standardised assessments particularly challenging.

Current diagnostic tools for ASD, while clinically validated, often rely on structured face-to-face observations conducted in unfamiliar and sometimes overstimulating environments. These may include hospital rooms or specialist clinics, where children are expected to perform social tasks on demand. For many neurodivergent children, especially those with high anxiety, limited verbal skills, or co-occurring conditions (e.g., epilepsy, dyspraxia), these settings do not accurately reflect how they behave in familiar or comfortable environments. The result is that valuable behavioural signals may be masked or misinterpreted, reducing the ecological validity of the assessment.

Furthermore, there are significant systemic barriers to accessing timely diagnostic services. Families may face long waiting lists, geographic constraints, and limited availability of autism specialists. Even when assessments are conducted, they often produce only a snapshot view of the child's abilities and struggles, rather than a rich, dynamic understanding of how the child engages over time. Additionally, traditional tools rarely integrate quantitative data from modern sensors (e.g., eye movement, reaction times, gesture dynamics), which could enhance the resolution and reliability of assessments.

To address these limitations, there is an urgent need for novel diagnostic tools that:

- Are non-intrusive and suitable for use in home or community environments
- Accommodate diverse sensory and motor profiles without requiring verbal responses
- Capture nuanced, quantitative data on social attention, emotional understanding, and motor coordination
- Are engaging, repeatable, and accessible for children aged 5 to 15 across a spectrum of abilities and backgrounds

The lack of such tools contributes to delayed diagnosis, misinformed intervention strategies, and heightened stress for families navigating the diagnostic process. By developing inclusive, technology-driven assessment methods that are grounded in naturalistic, playful engagement, we can create a more equitable and effective pathway to early identification and personalised support for children with ASD.

Solutions Proposed

Game-Based Assessment Framework

We developed a prototype plan involving two interactive games, each structured to assess key domains:

- **Social cognition**: through emotion recognition and joint attention
- **Motor response**: via touch-based interaction metrics

Children interact with avatars in themed environments (zoo, space, dinosaurs), receiving visual, auditory, and gestural cues that simulate emotional expressions. The in-app behaviour is recorded during the gameplay and analysed. The existing digital biomarkers from previous research are used for monitoring and assessment of users' in-app behaviour.

Multimodal Technology Stack

The framework integrates multiple non-contact sensing technologies to gather behavioural and cognitive metrics in real time:

- **Eye-tracking and Gaze Estimation**
  Using mobile-compatible solutions (e.g., EyeMU BEAM), the system captures metrics such as time to first fixation (TTFF), total fixation duration (TFD), and gaze-following accuracy to evaluate attention allocation and joint attention skills.
- **Facial Emotion Recognition**
  Leveraging computer vision models (e.g., Emotion-LLaMA, Smart Eye), the platform tracks facial expressions of the player and the in-game avatars. This supports analysis of affective resonance, empathy, and mimicry.
- **Touch and Motion Analysis**
  The games record finger velocity, pressure (where hardware supports), duration of touches, and the number of attempts. Motion tracking via built-in sensors further enables posture estimation and motor control evaluation.
- **Audio Interaction and Sonic Worldbuilding**
  Sound design includes empathetic music, ambient cues, and SFX to support children with different sensory needs. All audio features are toggleable to ensure sensory comfort. Games incorporate affirmative audio cues and allow blind/low-vision users to navigate via sound.
- **LLM-Augmented Adaptive Assessment**
  The system incorporates an LLM-based module to personalise assessments. It dynamically generates tasks and adjusts difficulty based on prior gameplay and contextual metadata (e.g., user history, time of day, caregiver input). LLMs are also used for generating questionnaire feedback, interpreting open responses, and suggesting caregiver interventions based on play data.

Study Design and Methodology

Phase 1: Planning (Months 1–3)

- Co-design workshops with families, clinicians, and neurodivergent individuals
- Ethics approvals and recruitment partner engagement
- Finalisation of in-game metrics

Phase 2: Implementation & Data Collection (Months 4–9)

- Pilot deployment in lab settings using tablets and eye-trackers
- Data collection in both game and real-world behaviours
- Integration of “React” (emotion recognition) and “Reflect” (confidence explanation) gameplay loops

Phase 3: Data Analysis (Months 10–11)

- Quantitative analysis of gaze, emotion, and motor metrics
- Validation against standardised tools like the Social Responsiveness Scale
- Machine learning classification to identify cognitive patterns

Phase 4: Final Reporting (Month 12)

- Prototype validation
- Usability report
- Roadmap for clinical and educational deployment

Considerations for Accessibility and Engagement

- **Inclusivity Features**
  Games support visual, auditory, and motor accessibility. For example, blind users may use audio navigation while deaf users can rely on vibration or visual cues. Interface design accounts for sensory sensitivity by avoiding flashing lights or sudden audio spikes.
- **Privacy and Ethics**
  The system architecture separates user data from application logic to support GDPR compliance. Raw behavioural data is anonymised, encrypted, and securely stored. Parents and caregivers are involved throughout, with opt-in consent models and transparent reporting.
- **Caregiver and Clinician Dashboard**
  A linked dashboard enables carers to log behavioural observations, track in-game progress, and access tailored reports. Clinicians can use these insights to inform decision-making and intervention planning.

This comprehensive, adaptive, and sensor-integrated approach represents a step-change in how social cognition and motor behaviour are assessed in ASD. By shifting the process into fun, interactive environments and enabling real-time data collection, the system holds the potential to reduce diagnostic wait times, lower family stress, and deliver early, personalised intervention pathways.

Future work

The current project lays the groundwork for a new generation of diagnostic tools that are mobile, multimodal, and meaningfully engaging for children with ASD. The development

of a validated prototype through this study opens several key avenues for future research and implementation.

First, the team plans to pursue feasibility studies to evaluate diagnostic sensitivity, usability, and clinical relevance in real-world conditions. These studies will involve broader demographic sampling across NHS trusts, special education providers, and community clinics. The aim is to assess the platform's performance in diverse populations, including children with co-occurring conditions, limited verbal communication, or atypical sensory profiles.

Second, the platform will be integrated into Neurometry's broader neurocognitive suite, which includes tools for assessing neurodegenerative and acquired brain injury populations. This will allow for shared infrastructure, streamlined analytics, and future cross-condition comparisons.

Third, there is strong interest in deploying the tool in community and school settings, particularly for early screening in underserved populations. The tool's portability and gamified structure make it ideal for non-clinical use, reducing barriers for families who struggle to access formal diagnosis pathways.

Fourth, the platform will be extended for longitudinal use, allowing repeated assessments over time. This will enable clinicians and caregivers to monitor developmental trajectories, evaluate the impact of interventions, and better understand intra-individual variability.

Finally, the system's modularity will support adaptation for other neurodevelopmental conditions, such as ADHD and Developmental Coordination Disorder (DCD). New game modules can be developed to capture additional cognitive and behavioural dimensions.

Ongoing improvements will focus on enhancing personalisation, including adaptive difficulty, gamified motivation mechanics, and machine learning-driven feedback that adapts content and analysis based on a child's profile.

Discussion and Conclusions

Participation in the N-CODE Study Group provided an invaluable platform for interdisciplinary problem-solving at the intersection of neuroscience, engineering, digital health, and inclusive design. The challenge of ASD assessment—particularly the need for tools that are accessible, engaging, and clinically valid—demanded contributions from a diverse team of researchers, developers, and stakeholders with lived experience.

The resulting prototype is not just a technical product but a conceptual shift in how we think about developmental assessment. By embedding clinically relevant metrics into game-based environments, we enable more naturalistic and less stressful assessments for

children. This, in turn, improves the ecological validity of data and opens up new opportunities for earlier and more precise diagnoses.

The approach aligns closely with the mission of N-CODE: to decentralise and democratise neurological assessment by making it community-based, technology-driven, and person-centred. Moreover, the co-creation process ensures that the tool is not only clinically sound but ethically grounded and responsive to real-world needs.

In summary, this project demonstrates the potential of gamified, sensor-based, AI-supported tools to transform neurodevelopmental diagnostics. With continued investment, iteration, and validation, we anticipate this platform becoming a valuable asset in both research and clinical practice, reducing inequities, empowering families, and improving outcomes for children with ASD.

References

1) A. Gallagher, C. Bulteau, D. Cohen, J.L. Michaud (Eds.), Handb Clin Neurol, vol. 173, Elsevier (2020), pp. 255-264, 10.1016/B978-0-444-64150-2.00022-8

2) Forby L, Anderson NC, Cheng JT, Foulsham T, Karstadt B, Dawson J, Pazhoohi F, Kingstone A. Reading the room: Autistic traits, gaze behaviour, and the ability to infer social relationships. PLoS One. 2023 Mar 1;18(3):e0282310. doi: 10.1371/journal.pone.0282310.

Appendix

Study group pictures.