# From Screen Viewing to Naturalistic Play: Mobile EEG for Ecologically Valid Assessment of Neural Dynamics in Young Children With and Without Autism

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## Synopsis

We investigated whether autism-related EEG differences observed in laboratory-style screen viewing remain detectable during ecologically valid, clinician-guided toy play. Thirty-six children (2–5 years; ASD n=15, TD n=21) completed passive video viewing and naturalistic play while wearing a wireless, four-channel mobile EEG system (F3/F4/C5/C6). Data were cleaned using artifact subspace reconstruction and analyzed via power spectral density and linear mixed-effects models. Central theta power (C5) showed significant group main effects, with TD children exhibiting higher theta power than ASD children across both contexts ($p$<.05), supporting robust mobile EEG markers in real-world interaction.

## Background

Autism spectrum disorder (ASD) is characterized by atypical social communication, restricted interests, and altered sensory–emotional processing. Electroencephalogram (EEG) has been widely used to study ASD, showing within group differences often reported in oscillatory activity, including theta band (Wang et al., 2013; Ortiz-Mantilla et al., 2019). However, recent large-scale reviews have noted that evidence for theta power differences in ASD remains inconsistent across varying paradigms and age groups (Neo et al., 2023). Additionally, most pediatric EEG studies rely on highly controlled and restricted laboratory environments with artificial tasks in which children are required to sit still and passively view stimuli on a screen. While this improves signal quality, it limits ecological validity and constrains our understanding of neural dynamics during natural, emotionally rich interaction.

Neuroergonomics seeks to characterize brain function in everyday contexts by integrating neuroscience methods with complex real-world tasks (Dehais et al., 2020). Recent advances in mobile neurotechnology (lightweight wireless amplifiers, child-friendly sensors, and improved artifact mitigation) now make it feasible to acquire EEG during movement and social engagement.

Here, we extend conventional screen-based EEG paradigms by collecting wearable mobile EEG from children with ASD and typically developing (TD) peers during both passive video viewing and a clinician-guided toy play session. We aimed to evaluate feasibility of obtaining analyzable mobile EEG during naturalistic play and to test whether group-level neural differences observed in traditional paradigms remain detectable in ecologically valid contexts.

## Methods

Thirty-six children 2-5 years of age participated in the study, including 15 children with a clinical diagnosis of ASD and 21 TD peers. ASD diagnoses were confirmed by clinical psychologist through thorough evaluation including Autism Diagnostic Observation Schedule, 2nd edition (ADOS-2) and caregiver interviews. All participants went through brief head sensor acclimation training before data collection day as previously described (Paolizzi, 2025).

Neural activity was recorded using a wireless Mentalab Explore EEG system sampling at 250 Hz with four wet electrodes positioned at F3, F4, C5, and C6 according to the international 10–20 system, referenced to linked mastoids. This sparse configuration was selected to balance participant comfort with signal reliability in mobile conditions. Each child completed two experimental conditions: a traditional screen-based task involving passive viewing of age-appropriate video clips, and a naturalistic play-based condition (Gagne et al., 2011) in which the child interacted freely with toys and a trained research staff, encouraging spontaneous social engagement and emotional expression (Lau-Zhu et al., 2019).

EEG data were bandpass filtered between 1 and 59 Hz and cleaned using artifact subspace reconstruction to mitigate movement-related noise inherent to mobile recordings (Klug and Gramann, 2021). Normalized band power was calculated with power spectral density for theta (4–7 Hz) for this analysis. Statistical analyses were conducted using linear mixed-effects models examining the fixed effects of Group (ASD vs. TD) and Activity (screen vs. play), with participant as a random factor.

## Results

Significant main effects of group (ASD vs. TD) were observed in the theta power band at central electrodes (C5) during both screentime ($F_{1,32.3} = 7.43$, $p < .05$) and playtime ($F_{1,30.1} = 5.03$, $p < .05$) conditions (Figure 1A–B). In each context, TD children exhibited significantly higher theta power than children with ASD (both $p < .05$). Crucially, the magnitude and direction of group differences were consistent across laboratory and naturalistic contexts, indicating that neural markers of ASD remain detectable during real-world interaction.

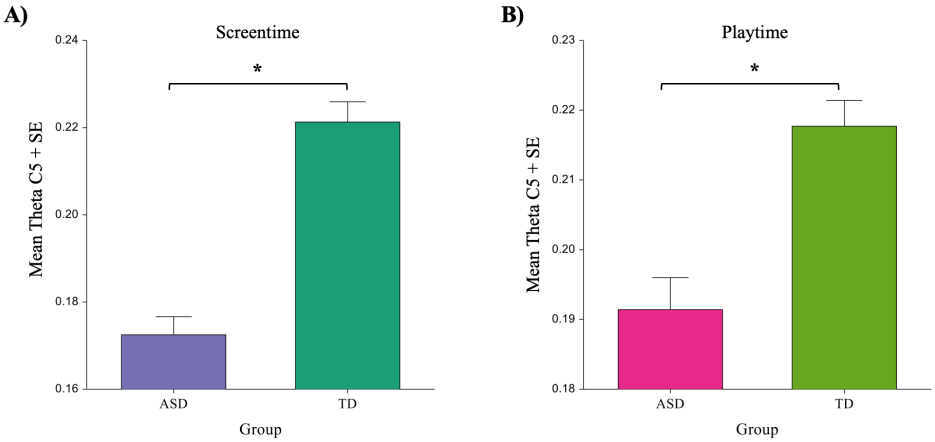


**Figure 1:** Mean normalized theta-band power at C5 ± SE during **A)** screentime and **B)** playtime for ASD and TD groups. (*$p < .05$).

## Discussion

This study examined EEG theta-band activity in young children with and without ASD during both structured screentime and ecologically valid, clinician-guided toy play using a lightweight wearable EEG system. Significant group differences were observed at central electrodes (C5) in both activity contexts, with TD children consistently exhibiting higher theta power than children with ASD during screentime and playtime. However, because C5 overlays the primary motor cortex, the reduced theta in the ASD group likely reflects atypical sensorimotor integration rather than isolated social cognition. The comparable magnitude and direction of these effects across conditions indicate that ASD-related differences in central theta oscillations are not limited to passive, low-movement tasks but persist during interactive, naturalistic behavior.

Theta oscillations are closely linked to attentional engagement and established literature maps attentional engagement to beta and social processing to gamma (Neo et al., 2023). Our findings highlight central theta as a potential marker of altered sensorimotor feedback during manual play. Importantly, the detection of consistent group differences during free play, despite increased movement and behavioral variability, demonstrates the capability of wearable EEG measures in real-world scenarios. Future analysis will incorporate comparison of the EEG features across the two conditions and other frequency bands. These findings support a neuroergonomic approach to developmental neuroscience, showing that neural markers of ASD remain detectable during everyday interactions and helping bridge laboratory-based measures with naturalistic social functioning.

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