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Stratifying cognitive and behavioral comorbidities in children with new-onset seizures – The influence of sociodemographic disadvantage☆

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ABSTRACT

Rationale: Children with new-onset epilepsy often experience co-morbid cognitive and behavioral challenges, which can be influenced by Social Determinants Of Health (SDOH) such as household income and parental education level. Although unsupervised machine learning has identified distinct cognitive and behavioral phenotypes at or near diagnosis, the relationship between these clusters remains underexplored. This study aims to examine the relationship between cognitive and behavioral clusters and the impact of SDOH among children with new-onset seizures.

Methods: We recruited 312 children (ages 6–16) within six weeks of their first recognized seizure. Each participant underwent a comprehensive neuropsychological assessment, from which factor analysis identified four primary domains: language, processing speed, executive function, and verbal memory. Parents also completed the Child's Behavior Checklist (CBCL). K-means cluster analysis was applied to the mean factor scores and CBCL T-scores to identify unique clusters. We assessed SDOH factors, including maternal education level, child's race, household income, and parental marital status, along with clinical epilepsy characteristics such as age at seizure onset, seizure frequency/intensity, seizure syndrome, MRI/EEG abnormalities, and neurologic examination findings to distinguish these clusters.

Results: We identified two primary clusters within both cognitive and behavioral scores: Resilient and At-Risk. Children in the Resilient Cognitive Cluster exhibited fewer behavioral problems, while those in the Resilient Behavior Cluster demonstrated higher cognitive performance. Conversely, the At-Risk Cognitive Cluster was associated with greater behavioral problems, and the At-Risk Behavior Cluster correlated with lower cognitive performance. Notably, almost two-thirds of participants showed congruence in clustering, either displaying resilience in both cognition and behavior or vulnerability in both domains. Resilient children exhibited lower levels of sociodemographic disadvantage, whereas those in the At-Risk Clusters faced significant disadvantages. Sociodemographic factors were more pronounced in differentiating clusters compared to traditional clinical epilepsy characteristics.

Conclusions: Among children with new-onset seizures, some display significant resilience to multimorbidities, while others are particularly vulnerable to neurobehavioral challenges, often linked to sociodemographic disadvantages. Future research should explore whether early interventions targeting SDOH can mitigate these risks and improve outcomes for children with new-onset epilepsy.

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1. Introduction

Children with epilepsy can experience alterations in brain development compared to typically developing children [1]. These developmental alterations may not only lead to the development of seizures, but also result in differing trajectories in cognition and behavior development [2–4]. Consequently, beyond the primary condition of epilepsy, a notable subset of youth with new-onset epilepsy experience substantial cognitive and behavioral comorbidities that can pre-date the diagnosis of epilepsy and result in learning and academic challenges [5–7]. Children with epilepsy may exhibit cognitive impairments that can range from mild learning difficulties to severe intellectual disabilities. Additionally, behavioral issues, including anxiety, depression, and ADHD, are prevalent among children with epilepsy [8–10]. These cognitive and behavioral challenges are exacerbated by factors such as the age of onset, seizure frequency, and type of epilepsy [11].

Accumulating evidence consistently illustrates that the Social Determinants of Health (SDOH) influence the diagnosis, medical care, treatment, and outcomes of various diseases—and in this regard, epilepsy is no exception [12]. In addition to the multiple clinical epilepsy features that may exert a significant impact on the presence and course of these comorbidities (including epilepsy syndrome, age of onset, chronicity, and seizure frequency/severity [7,13–16]), sociodemographic and socioeconomic background also play a substantial role.

Specifically, SDOH has been found to play a noteworthy role in the outcomes of youth with epilepsy, not only regarding seizure-related outcomes, but also regarding the developmental trajectories of cognition and behavior. Understanding how sociodemographic factors influence these comorbidities and their course is crucial for developing effective interventions. Recent evidence demonstrates that children with epilepsy from disadvantaged backgrounds are at an even greater risk for cognitive and behavioral impairments. Living in a disadvantaged neighborhood, for instance, is correlated with poor access to adequate healthcare, public transportation, educational resources, and supportive services [17,18]. Other sociodemographic disadvantages, such as a lower socioeconomic status (SES) and a minoritized/marginalized status (for instance, based on religion, race, ethnicity, or disability) can further compound these neurobehavioral issues by fostering environments that are less supportive of emotional well-being while limiting health insurance options and access to necessary mental health resources [19–21]. Low SES is associated with increased stressors that can negatively impact both the child and family dynamics. For instance, families facing economic hardships may experience higher levels of stress, which can in turn affect the mental health of parents as well as children [22,23]. Additionally, children from minoritized backgrounds may face systemic barriers that hinder their access to adequate healthcare and educational support, further complicating their primary condition and associated comorbidities. On the whole, it is increasingly appreciated that sociodemographic factors play a critical role in the development and exacerbation of cognitive and behavioral comorbidities in children with new-onset epilepsy [24,25].

Within the population of children with epilepsy, there are subgroups exhibiting positive health outcomes, while others experience less favorable results. In this paper, we employ advanced analytical techniques to stratify the behavioral and cognitive comorbidities in children with new-onset seizures into distinct clusters. We also delve into the extent to which SDOH and other clinical epilepsy characteristics contribute – just a few of the many factors resulting in significantly diverse health outcomes in children with new-onset epilepsies. Our aim here is to elucidate the complex interplay between new-onset seizures, cognitive and behavioral issues, as well as sociodemographic disadvantage in a pediatric population.

2. Brief methods

2.1. Participants

312 children with newly diagnosed seizures (aged 6–16 years) were recruited within 6 weeks of their first recognized seizure (Mean = 35 days). All children in this sample met International League Against Epilepsy criteria for epilepsy [26]. Parental informed consent and child assent were obtained prior to data collection. The study was approved by the institutional review boards at Indiana University and Cincinnati Children's Hospital Medical Center.

Exclusion criteria for both children with seizures and siblings were: a co-morbid chronic physical disorder, intellectual disability (based on either clinic records or parent report – an IQ of 70 or above on screening), or seizures precipitated by an acute event (e.g., intracranial infection, metabolic derangement, and recent head injury). Children who had had two or more febrile but no afebrile seizures or who were placed on daily antiseizure medication (ASM) after a febrile seizure were also excluded. In addition, children with infantile spasms (hypsarrhythmia), electrical status epilepticus in sleep (ESES) and epilepsy with continuous spike-wave during slow wave sleep (CSWS) were excluded from the study.

2.2. Cognitive measures

All children completed a comprehensive neuropsychological evaluation that included standardized clinical measures of intelligence, language, immediate and delayed verbal and visual memory, executive functions, speeded fine motor dexterity, and academic achievement. Each administered test had associated normative data for which the available sociodemographic data were adjusted. The specific administered tests included: Clinical Evaluation of Language Fundamentals, 3rd Edition (CELF-3) [27]; Comprehensive Test of Phonological Processing (CTOPP) [28]; Conners' Continuous Performance Test, 2nd Edition, (CPT-II) [29]; Kaufman Brief Intelligence Test (K-BIT) [30]; Coding and Symbol Search Subtests of the Wechsler Intelligence Scale for Children, 3rd Edition (WISC-III) [31]; Wide Range Assessment of Memory and Learning (WRAML) Design Copy [32]; and the Wisconsin Card Sorting Test (WCST) [33].

To assess intelligence, the full-scale K-BIT IQ score was used. All youth had an IQ equal to or greater than 70. In addition, each test was administered according to standardized procedures and scores were converted to age-corrected standardized scores using the best available national norms for all tests except WRAML Design Copy, which was designed by this study's research group [46]; this test was normed internally, using our own sample to generate age-corrected scores.

Factor analysis of this neuropsychological test data revealed four underlying factors: (1) Language, (2) Processing Speed, (3) Executive Function/attention/construction (EF), and (4) Verbal Memory and Learning [34,35]. Higher factor scores indicate better neuropsychological performance [36]. For each participant, the mean of all four cognitive factor scores was collated.

2.3. Behavior measures

The CBCL was completed by a caregiver/parent to assess each the presence and degree of each child's behavior problems during the prior 6 months. Details are described elsewhere [35,37]. Briefly, the CBCL has 118 items describing behaviors that are rated using 3-point scales of 0 (*not true*), 1 (*somewhat or sometimes true*), and 2 (*very true or often true*) [38]. Parents were specifically instructed to exclude any behaviors that might have represented actual seizure activity or any behaviors that occurred immediately prior to, or after, a seizure. The summary score from the CBCL – T-scores for Total Behavior Problems – is normed for age and sex with higher T-scores indicating more problematic behavior levels.

2.4. Sociodemographic characteristics

Sociodemographic data (household income, mother's highest education level, mother's marital status, and the child's self-identified race) were collected as contributors to social determinants of health. A sociodemographic score (SD) score was computed based on the four sociodemographic variables, the details discussed elsewhere [24,25]. Briefly, for caregiver education level and household income, those families below the mean were assigned a score of *0*, while those families at or above the mean were assigned a score of *1*. For race and caregiver marital status, non-white race and non-married status were each assigned a score of *0*, while white race and married status received a score of *1*. The SD score is the sum of all disadvantage variables, ranging from 0 to 4. SD groups 0, 1, and 2 were collapsed together, while SD groups 3 and 4 were collapsed together, resulting in two distinct groups comprising a Low Disadvantage Group and a High Disadvantage Group.

2.5. Clinical epilepsy characteristics

In addition to general demographic data (e.g., child's age, child's biological sex, child's grade), clinical seizure characteristic data (e.g., age of onset of first recognized seizure, seizure burden (number of seizures/year), and percent taking anti-seizure medications (ASM)) were collected. Other clinical seizure variables including seizure classification, results of neurological examination, electroencephalogram, and imaging were collected from the electronic medical record and were coded independently by study physicians blinded to the cognitive data.

2.6. Statistical analysis

2.6.1. K-means clustering

Using the Statistical Package for Social Sciences (SPSS) software (Version 29.0, IBM, Chicago IL), K-Means Clustering was employed to stratify behavior and cognitive comorbidities in children with new-onset epilepsies into distinct cluster groups. A uniform cluster analysis methodology focused on a two-step approach. In the first step, hierarchical cluster analysis using Ward's method generated a dendrogram to estimate the number of likely clusters within the studied population. The estimate was pre-specified in a k-means cluster analysis that was used as the principal clustering technique [39]. Average Cognitive Factor Score and CBCL Total Behavior T-scores were used for the analysis. The clustering analysis determined two distinct clusters for Average Cognitive Factor Score (a *Resilient Cognitive Cluster and an At-Risk Cognitive Cluster*) and two distinct clusters for CBCL Total Behavior T-scores (a *Resilient Behavior Cluster and an At-Risk Behavior Cluster*). As a consequence, children with new-onset seizures could fall into one of four categories – (1) Resilient Cognitive/Resilient Behavior, (2) Resilient Cognitive/At-Risk Behavior, (3) At-Risk Cognitive/Resilient Behavior, and finally (4) At-Risk Cognitive/At-Risk Behavior.

The between-cluster comparisons of baseline parameters were conducted using one-way analysis of variance (ANOVA) and crosstabs chi-square. When the F statistic was significant, Tukey Honest Significant post-hoc comparisons were conducted.

3. Results

3.1. Baseline demographics

Table 1 summarizes the demographic characteristics and clinical seizure characteristics of children with seizures. Briefly, a total of 312 children with newly diagnosed seizures aged 6–16 years were included in the analyses. The clinical epilepsy characteristics indicate that the children with seizures in this sample had an average age of onset of seizures of 9.49 years of age and about 65 % of the seizure group was comprised of focal epilepsy syndromes. The five most frequently prescribed ASMs were lamotrigine, oxcarbazepine, carbamazepine, phenytoin and valproic acid. Other less commonly prescribed medications included levetiracetam, ethosuximide, zonisamide, and gabapentin. The epilepsy syndromes were divided into two groups: Primary Generalized (generalized tonic-clonic, absence, and myoclonic epilepsy syndromes) and Focal/Localization-Related (focal unaware and focal aware seizures with or without secondary generalization). In this cohort, MRI abnormalities included multiple various abnormalities (e.g., bilateral or unilateral hippocampal atrophy/sclerosis, ventricular enlargement, volume loss, cortical dysplasias, heterotopias, angiomas, encephalomalacia, and old hemorrhages) as described in detail elsewhere [40]. The EEG abnormalities included focal and generalized epileptiform activity (localized and generalized intermittent slowing, continuous slowing, epileptiform discharges, electrographic seizures, occipital intermittent delta activity, and frontal intermittent delta activity). In this cohort, 62 % evidenced epileptiform activity, 11 % slow wave activity, and 1 % electrographic seizures [36].

Table 1
Sample Characteristics for Children with Seizures. Data presented as mean (SD). SD = standard deviation, %=percent, M/F = male/female. FUS – Focal Unaware Seizures. (Income adjusted for today's dollar value).

	Children with Seizures
Group Characteristics	
Sample Size	312
Child's Age, years (SD)	9.44 (2.6)
Child's Sex M/F	158/154
Child's IQ (SD)	100.96 (15.3)
Grade, years (SD)	3.79 (2.45)
Clinical Epilepsy Characteristics	
Age of Onset, years (SD)	9.58 (2.54)
Seizure Frequency, per Year (SD)	43.32 (174.71)
% With FUS (Most Common Seizure Type)	41.7 % FUS
% With Generalized Seizure Syndrome	38.6 %
% With ≥ 2 Seizure Types	8.5 %
Household/Mother Sociodemographic Characteristics	
Self-Identified Race (%White/Caucasian)	78.8 % White
Mean Household Income (SD)	$60–70 k ($27.5 k)
Mean Caregiver Education, years (SD)	13.82 (2.25)
% Married	76 % married

3.2. Stratifying behavior and cognitive risk in children with new onset seizures

For both behavior and cognition, *K-Mean Cluster* analysis resulted in two distinct clusters each representing *good clustering quality*. The two clusters identified were – Cluster 1 (Resilient Cluster) and Cluster 2 (At-Risk Cluster) for both behavior and cognition.

An ANOVA assessed differences in behavior and cognition between the two cluster groups, those in the At-Risk Behavior Cluster also demonstrated poorer cognitive performance ($F(1,287) = 24.3$, $p < 0.001$, See Fig. 1A, in blue). Similarly, those in the At-Risk Cognition Cluster also exhibited higher average levels of behavioral problems ($F(1,287) = 27.9$, $p < 0.001$, See Fig. 1B, in red). On the other hand, those in the Resilient Behavior Cluster demonstrated better average cognitive performance (See Fig. 1A, in blue). Similarly, those in the Resilient Cognition Cluster showed lower average levels of behavioral problems (See Fig. 1B, in red). In summary, this indicates that cognition and behavior are "co-travelers" in the sense that the intact vs impaired status of one dependent measure (e.g., cognition) is linked with abnormality in the other (e.g., behavior).

3.3. Congruency between clusters

To further evaluate this 'co-traveler' status between cognitive and behavior comorbidities, we investigated the extent of congruency amongst the clusters. Using crosstabs analysis, we found a significant pattern of congruency such that children in the Resilient Behavior Cluster had a higher chance of also being stratified into the Resilient

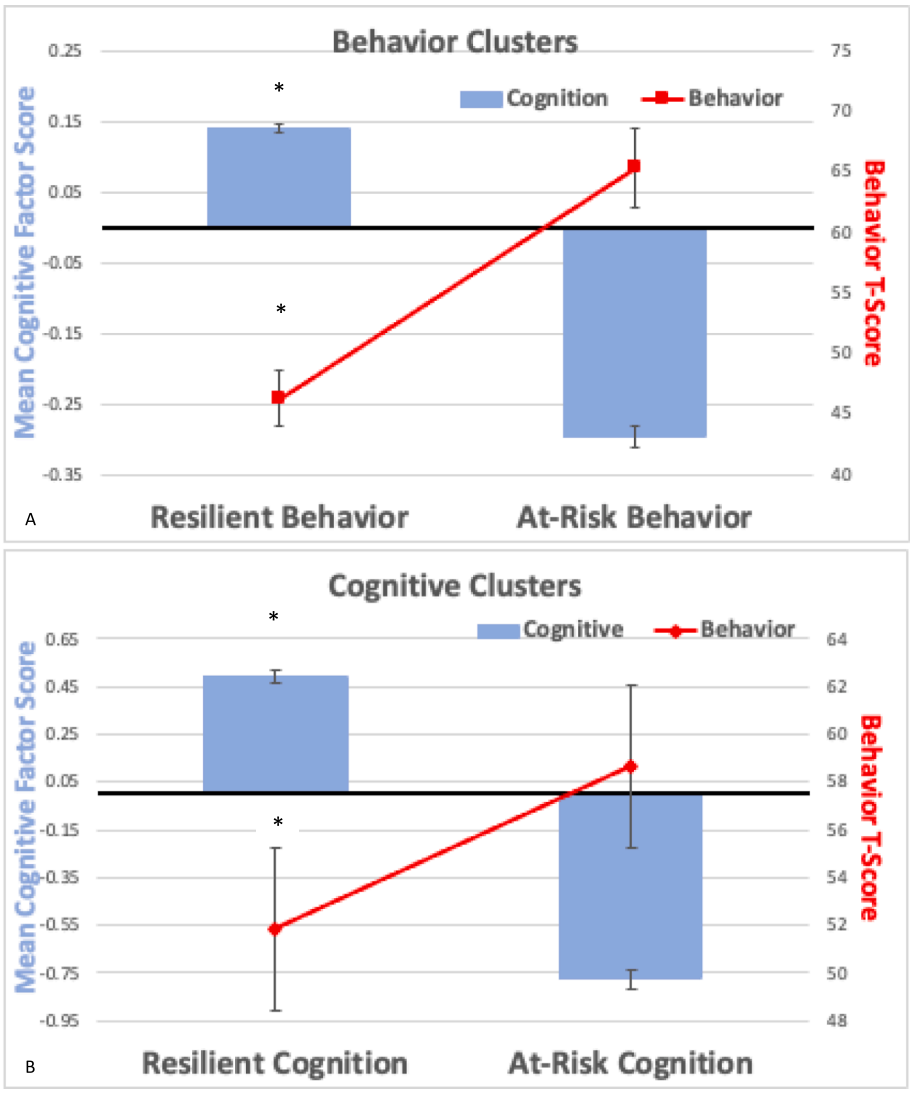

Fig. 1. A&B. Behavior and Cognition Cluster. Those in At-Risk clusters (Behavior or Cognition) exhibit poor cognition and behavior, while those in Resilient clusters (Behavior or Cognition) exhibit better behavior and cognition performance. *p<0.01.

Cognition Cluster, while the children within the At-Risk Behavior Cluster are more likely to also fall into the At-Risk Cognition Cluster ($\chi^2(1, N = 311) = 8.9$, $p = 0.005$) (See Table 2). Overall, children with new-onset seizures have a ~ 2/3 chance of being stratified into congruent clusters (i.e., *Resilient* Clusters for both Cognition and Behavior or *At-Risk* Clusters for both Cognition and Behavior) (See Fig. 2). More specifically, 36.6 % (N = 105) of the sample were in the Resilient Behavior/Resilient Cognition group, while the 29.1 % (N = 89) of the sample were in the At-Risk Behavior/At-Risk Cognition group, resulting in almost two-thirds of the children exhibit congruency in Behavior and Cognition.

Table 2
Congruency of Clusters Groupings. High congruency between Resilient Clusters. In addition, there is high congruency between At-Risk Clusters. *P < 0.01.

	Resilienta Behavior Cluster (N = 155)	At-Risk Behavior Cluster (N = 157)
Resilient Cognition Cluster (N = 164)	65.2 %*	34.8 %
At-Risk Cognition Cluster (N = 125)	29.6 %	60.4 %*

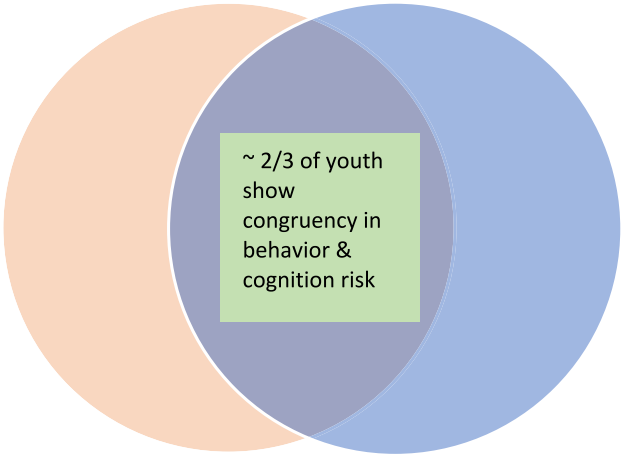

Fig. 2. Congruency of Behavior and Cognition Risk.

3.4. Characteristics of congruent and incongruent groups

We further explored the relationship between congruence and incongruence in the Behavior and Cognition Clusters. For the congruent groups, we found that those in the At-Risk Behavior/At-Risk Cognitive groups showed the poorest cognitive performance and highest levels of behavioral problems on average, while those in the Resilient Behavior/Resilient Cognitive groups showed the highest levels of cognitive performance and lowest levels of behavioral problems on average also experiencing poorer cognitive performance (Cognition: $F(3,283) = 186.8$, $p < 0.001$; Behavior: $F(3, 283) = 223.1$, $P < 0.001$, See Fig. 3). For the incongruent groups, those in the At-Risk Cognitive/Resilient Behavior group and those in the Resilient Cognitive/At-Risk Behavior group exhibited behavior and cognitive scores that fell in mid-range between the congruent groups (Fig. 3).

3.5. Sociodemographic characteristics of clusters

In addition to evaluating the four SDOH factors (see Table 3), we assess the SDOH groups – Low Disadvantage and High Disadvantage Groups. Youth with new-onset seizures in the At-Risk and Resilient Behavior and Cognition Clusters were evaluated to determine distinguishing demographic patterns. The analysis resulted in significant differences in sociodemographic background in both Behavior and Cognition groups ($\chi^2(7, N = 274) = 37.71$, $p < 0.001$). Further crosstabs analysis indicated that youth with new-onset seizures in the At-Risk Behavior/At-Risk Cognitive group (Behavior – $\chi^2(3, N = 311) = 12.44$, $p = 0.006$; Cognition – $\chi^2(3, N = 289) = 8.9$, $p = 0.005$) had the highest odds of coming from a more disadvantaged background. On the other hand, youth with new-onset seizures in the Resilient Behavior/Resilient Cognitive group had the lowest odds of coming from a more disadvantaged background.

3.6. Clinical epilepsy characteristics of clusters

Here, clinical characteristics for youth with new-onset seizures who fell into congruent and incongruent Behavior and Cognitive Clusters were investigated. Analysis of the Resilient Clusters group versus At-Risk Clusters group indicated significant differences in age, child's IQ, child's grade, age of onset, and neurologic exam findings (Table 4). The analysis indicated that youth with seizures in the At-Risk Clusters groups had increased odds of having a younger age of onset of seizures, lower global intellectual ability performance (IQ), and an abnormal neurologic examination.

4. Discussion

The goals of this paper were to: (1) characterize and stratify the degrees of behavioral and cognitive vulnerability and resilience in children with new-onset epilepsies, (2) explore the interdependence or co-occurrence of these two important comorbidities—so called multimorbidity, (3) characterize the relationship between sociodemographic disadvantage and At-Risk/Resilient Behavioral/Cognitive Cluster groups, and to (4) relate the influence of SDOH on this multimorbidity to that of traditional clinical epilepsy characteristics.

Using the k-means clustering approach, we identified robust *Resilient* and *At-Risk* Clusters when examining both cognition and behavior. Stratifying the risk of cognitive and behavioral challenges in children with new-onset seizures has recently been gaining traction in the field of epilepsy as specific subsets of youth are more vulnerable, while others less so [41–46]. Our findings corroborated the literature, while extending our knowledge by indicating the pattern of risk. By categorizing youth based on patterns in their cognitive and behavioral profiles, the findings revealed distinct groups with differing levels of resilience and vulnerability. With this stratification, we also gained insights into which children exhibited cognitive strengths despite behavioral challenges and vice versa. This approach ultimately provides a more nuanced understanding of the interplay between cognitive and behavioral factors, highlighting specific areas where interventions could be targeted to support At-Risk individuals or to enhance resilience in those already demonstrating Resilient Cognitive and Behavioral outcomes.

Second, there was considerable but not identical coexistence of the Resilient Cognitive and Resilient Behavioral Clusters as well as 'co-traveling' or coexistence of the At-Risk Cognitive and At-Risk Behavioral Clusters. This interdependence or multimorbidity is increasingly recognized [7,47]; indicating that these comorbidities need to be considered and investigated more comprehensively. Further, the pathways leading to congruence or incongruence between cognitive status

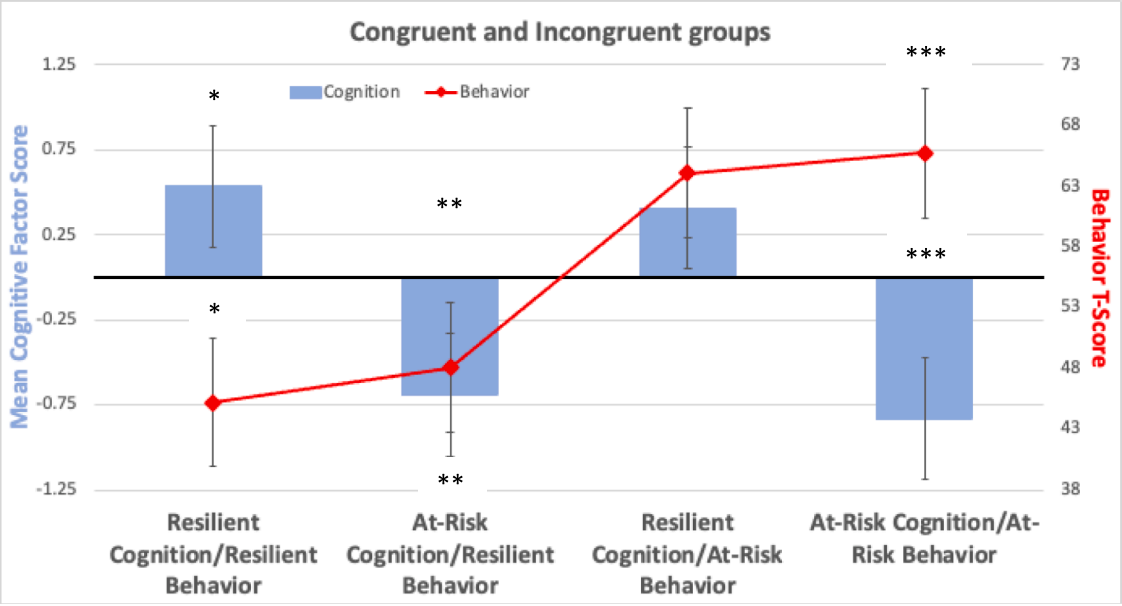

Fig. 3. Congruent and Incongruent Behavior and Cognition Clusters. Those in At-Risk Behavior Clusters exhibit poor behavior and those in At-Risk Cognitive Clusters exhibit poor cognitive performance. On the other hand, those in Resilient Behavior Clusters exhibit better behavior and those in Resilient Cognitive Clusters exhibit better cognitive performance. No star differs from *, * differs significantly from **, ** differs significantly from ***.

Table 3
Comparisons of sociodemographic characteristics of the At-Risk and Resilient Clusters groups. Notably, all SDOH categories show significant differences. No star differs from *, * differs significantly from **. (Income adjusted for today's dollar value).

Cluster Characteristics	Resilient Behavior / Cognition Clusters (N = 105)	Resilient Behavior / At-Risk Cognition Clusters (N = 61)	At-Risk Behavior / Resilient Cognition Clusters (N = 57)	At-Risk Behavior / Cognition Clusters (N = 89)	F/χ^2	P
Average Household Income	$70–80 K	$60–70 K	$75–85 K	$50–60 K*	9.86	0<.001
Average Mother's Highest Education Level	14.25 years (2.2)	14.08 years (2.4)	14.05 years (2.0)	13.0 years (2.4)*	4.94	0.002
Mother's marital status	81.7 % married	79.6 % married	83.9 % married	64.9 %* married	3.15	0.026
Self-Identified Race	94.3 % white	72 %* white	84.2 % white	74.7 %* white	6.21	0<.001
Sociodemographic Background (% High Disadvantage)	16 %	31.3 %*	15 %	51.4 %**	13.13	0<.001

Table 4
Comparisons of characteristics of the At-Risk and Resilient Cluster groups. Notably, age, child's IQ, child's grade, age of onset, and neurologic exam findings show significant differences. Significance depicted in bold (*$p < 0.05$, ~$p < 0.1$).

Cluster Characteristics	Resilient Behavior / Cognition Clusters (N = 105)	Resilient Behavior / At-Risk Cognition Clusters (N = 61)	At-Risk Behavior / Resilient Cognition Clusters (N = 57)	At-Risk Behavior / Cognition Clusters (N = 89)	F	P
Group Characteristics						
Child's Age, years (SD)	**9.65 (2.5)**	**8.04 (2.0)***	**10.1 (2.8)**	**9.51 (2.5)**	**6.71**	**0<.001**
Child's Sex (%F)	57.1 %	56 %	52.6 %	42.7 %	1.35	0.258
Child's IQ (SD)	**110.95 (10.7)**	**95.7 (10.2)***	**107.1 (10.4)**	**89.17 (13.6)****	**62.13**	**0<.001**
Grade, years (SD)	**4.11 (2.4)**	**2.61 (1.98)***	**4.6 (2.6)**	**3.63 (2.35)**	**6.78**	**0<.001**
Clinical Epilepsy Characteristics						
Age of Onset, years (SD)	**9.81 (2.5)**	**8.25 (2.0)***	**10.21 (2.5)**	**9.55 (2.4)**	**6.44**	**0<.001**
Seizure Frequency, per Year (SD)	54.7 (205.5)	72.4 (230.7)	17.02 (39.5)	25.9 (119.6)	1.37	0.253
% With Generalized Seizure Syndrome	31.4 %	38.0 %	26.8 %	36.5 %	0.686	0.561
MRI findings (% normal)	77.2 %	60.5 %	65.5 %	66.2 %	1.76	0.155
EEG findings (% normal)	28.6 %	18 %	25 %	24.3 %	0.676	0.567
Neurologic Exam findings (% normal)	**99 %**	**98 %**	**98.2 %**	**89.2 %***	**4.53**	**0.004**
Anti-seizure medications (% on ASMs)	15.2 %	12 %	12.3 %	14.7 %	0.094	0.963

and behavioral status remain to be determined including whether additional factors account for their presence and severity. It is also important to note that nearly 40 % of youth we evaluated showed high resilience; with low risk for both cognitive and behavior challenges. This is a promising finding, indicating that not all youth with epilepsy inevitably experience these multi-morbidities.

Third, the role of SDOH is further demonstrated here. Children with new-onset seizures from disadvantaged backgrounds exhibited greater cognitive and behavioral impairment compared to their less disadvantaged counterparts, indicating higher levels of vulnerability and suggesting a higher risk of ongoing neurobehavioral challenges. This corroborates other studies that indicate that children from disadvantaged backgrounds often perform lower on standardized cognitive assessments, reflecting the cumulative impact of environmental stressors and limited access to supportive services [20,22]. Although there is often a predominant emphasis on medical care of epilepsy, it is acknowledged that medical care constitutes just one of the components influencing an individual's health outcome. Indeed, medical care plays a crucial role in determining an individual's health, yet it is only accountable for 10–15 % of preventable morbidity and mortality in the U.S., which affirms the significance social factors play in shaping an individual's overall health [48]. A recent *meta*-analysis determined that in the year 2000, the impact of factors such as low education, racially based discriminatory laws, and low social support on health outcomes in the U.S. was comparable to the impact of specific health conditions like myocardial infarction, cerebrovascular disease, and lung cancer [49]. So, to meaningfully enhance the health outcomes of patients, it is imperative to delve into the impact of social determinants of health. While numerous papers often concentrate on inherent individualized characteristics like age, race, and biological sex to investigate health outcomes, it is important to expand investigation further by not only delving into the intrinsic traits of individuals but also exploring the structural factors external to an individual's control that significantly impact their health and quality of life. The degree to which individual factors of disadvantage, including the social construct of race as well as age, income, education, and stability affect health outcomes compared to structural factors of disadvantage, such as zip code, health insurance, transportation, and the presence of food deserts would be an important area of investigation as both play a crucial role in determining a patient's well-being [50–52].

Finally, the results of our study indicate that in comparison to other clinical epilepsy characteristics, the influence of sociodemographic disadvantage is quite striking. This indicates the need for further evaluation from a research standpoint while also incorporating the impact of sociodemographic disadvantage into our clinical evaluation and treatment approaches in a culturally humble and respectful manner [53,54].

This study has limitations that should be mentioned. First, evaluation of academic achievement was limited in scope. We also did not assess disorders such as dyslexia and attention deficit disorders, which can adversely affect cognitive and academic performance. Second, the specific epilepsy syndromes evaluated here were limited. We did not evaluate any epileptic encephalopathy syndromes and other disorders such as Lennox-Gastaut syndrome. As a consequence, the inferences of our findings are not generalizable to all pediatric epilepsies. The majority of our patients had focal epilepsy; however, about one-third of our patients had generalized seizures, which may have a genetic component and increases familial risk of epilepsy. Genetic testing was not performed in this study. Furthermore, the cause and inciting factors that precipitated the epilepsy were not assessed and may have played a role in the cognitive and behavioral findings we presented. We do not have these

data and could not include this information in our analyses.

Despite these limitations, our findings underscore the often-articulated need for a multidimensional approach to the treatment of children with new-onset epilepsies. Interventions must consider not only the medical management of seizures but also the cognitive and behavioral health of the child. Additionally, the essential message provided by SDOH investigations of cognitive and behavioral morbidities including this one, is that addressing the sociodemographic disadvantages faced by these children is critical. Programs aimed at improving access to healthcare, mental health, and associated educational resources could mitigate some of the negative outcomes associated with epilepsy. Furthermore, programs and services aimed at supporting parents and caregivers experiencing these SDOH stressors could positively influence the overall cognitive and behavioral health of these youth with epilepsy.

In conclusion, Michael Duchowny appreciated the presence of cognitive and behavioral comorbidities in children with epilepsy and the undue influence of sociodemographic disadvantage on epilepsy outcomes. Here, we honor his legacy by highlighting the co-existence of these three factors – cognitive challenges, behavioral challenges, and the associated role of SDOH in youth with new-onset seizures. Addressing these disparities is essential for improving outcomes and enhancing the quality of life for affected children. Based on our overall findings, beneficial future research would further elucidate the connections between cognitive and behavioral health in children with new-onset seizures. For example, clustering combined cognitive and behavioral scores may provide deeper insights into these interrelationships. In addition, future research should not only continue to explore these relationships, but also focus on developing targeted interventions that consider the unique challenges faced by children from disadvantaged backgrounds.

5. Tribute to Michael Duchowny

In this publication, we want to honor Dr. Michael Duchowny, a distinguished pediatric epileptologist whose unwavering commitment to patient care, education, and research profoundly influenced the field of epilepsy and the lives of countless children with epilepsy and their families. Dr. Duchowny was fully committed to caring for youth with epilepsy and improving the arc of their life trajectories. He was amongst the first to recognize the critical role that cognitive and behavioral challenges posed to the quality of life of youth with epilepsy [1]. Not just a skilled clinician, he was a tireless advocate for children with epilepsy from all backgrounds. As an accomplished researcher, he frequently emphasized the importance of understanding each child's unique experience with epilepsy in his publications, recognizing that every patient is more than just a diagnosis. This holistic approach fostered an environment where families from all backgrounds felt heard, valued, and supported.

Dr. Duchowny not only contributed substantially to our understanding of epilepsy and the paths to improve the surgical approaches and outcomes for youth with complicated epilepsies, but he also paved the way for innovative perspectives when considering the cognitive and behavioral comorbidities that can adversely affect the lives of children with epilepsy. His work fostered a collaborative and inclusive environment while caring for children with epilepsy from multicultural and multilingual backgrounds with compassion. He consistently appreciated and evaluated the role of sociodemographic disadvantage and social determinants of health in epilepsy outcomes. This commitment not only worked to destigmatize the condition but also provided invaluable resources for families navigating the challenges of epilepsy. He approached his clinical research by believing that every child deserved access to quality care and support; and he passionately advocated for vulnerable populations. His remarkably inspiring legacy lies not only in the advancements he made in the field of epilepsy research but also in the countless lives he touched. He was highly inclusive in a collaborative sense, always involving neuropsychology, social work, nursing, educational programs, and other related disciplines in his work —always in the hope of improving the eventual life course of children with epilepsy.

In this contribution, our goal is to honor Dr. Duchowny's work by highlighting the behavioral and cognitive comorbidities that can be observed in children with new-onset epilepsies, emphasizing the role and influence of social determinants of health in their neurobehavioral outcomes.

CRediT authorship contribution statement

Karina Morales: Writing – original draft, Resources, Investigation, Conceptualization. **Tracy De Los Santos:** Writing – review & editing, Investigation, Conceptualization. **Danielle Harvey:** Validation, Methodology, Investigation, Formal analysis. **David Dunn:** Visualization, Supervision, Resources, Methodology, Data curation, Conceptualization. **Jana Jones:** Visualization, Validation, Supervision, Investigation, Conceptualization. **Anna Byars:** Methodology, Investigation, Data curation, Conceptualization. **Joan Austin:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Bruce Hermann:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Temitayo Oyegbile-Chidi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.yebeh.2025.110267.

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